

# **Simulation and Analysis of Three Congested Weigh Stations using Westa**

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## **Executive Summary**

### **Introduction**

This paper documents studies of three congested weigh stations. At each station current operating policy and traffic levels result in frequent occasions where the queue of trucks threatens to back up onto the highway, and the scales must be closed to avoid overflow. Overweight trucks and trucks with safety or credential problems may be missed when that happens. At each station, some alternate configurations have been proposed to solve the current problem and deal with anticipated increases in truck traffic. The studies provide one way of analyzing the proposed improvements.

The studies used the Westa (Weight Station) simulation model to represent the current and alternate scenarios. Westa is a detailed simulation of truck, car, and other traffic around inspection stations. Model development and the current analysis were funded by the Federal Highways Administration (FHWA) Joint Program Office (JPO) for Intelligent Transportation Systems (ITS), with support from the FHWA Office of Motor Carriers (OMC) Size and Weight team. Studies were performed for three state agencies as a pilot test of the accuracy and applicability of the Westa model.

### **Case Studies**

The first study addresses three alternative approaches proposed by the Indiana State Police and Indiana Department of Transportation for reducing congestion at the Seymour, Indiana weigh station on northbound Interstate I-65. The first approach is the use of transponders on trucks and roadside devices capable of reading them at highway or ramp speeds. The study varies from 5% to 50% the percentage of trucks with transponders bearing the proper information for bypassing the weigh station. The second approach is to use a low-speed Weigh-in-Motion (WIM) scale within the station to pre-screen the trucks. Trucks weighing less than a specified threshold value may bypass the static scale on a new bypass lane. The third approach is to lengthen the approach ramp by 1,000 feet or by 2,000 feet to hold longer queues.

The second study addresses a proposed replacement for the McCook Port of Entry inspection station near the point where traffic enters South Dakota on northbound Interstate I-29. The South Dakota Department of Transportation is considering building a replacement station nearby, using a low-speed Weigh-in-Motion scale within the station to pre-screen the trucks. Trucks weighing less than a specified threshold value may bypass the static scale on a special bypass lane. The study modeled a policy where all trucks measured as overweight by the WIM would be weighed at the static scales, and a policy where a randomly selected percentage of such trucks would be weighed.

The third study modeled the Lehi weigh station, located on eastbound Interstate I-40 near the Arkansas/Tennessee border. The Arkansas Highway and Transportation Department is considering upgrading the station, and building a new station nearby. The first alternate configuration represents the addition of a second static scale, doubling the station's weighing capacity. The second alternate configuration modeled the addition of a mainline WIM scale in advance of the station. The third alternate configuration was the combination of the dual static scales and the mainline WIM scales.

### **Analysis Approach**

Data reflecting current traffic levels and characteristics and current station operations were collected at each of the stations and at nearby locations by the three state agencies. Mitretek designed base case scenarios that confirmed congestion at each weigh station and realistically modeled the station or scales closing when the entrance ramp backed up. Officials at each site were asked to concur that the base case models accurately represented the operation of the current facility before Mitretek continued with analysis of alternate scenarios.

Following validation of the base case scenarios, Mitretek designed alternate scenarios as defined by the state agencies, and ran multiple iterations of each scenario. The results indicate various benefits for transponder equipage, WIM scales, and dual static scales. These benefits are represented in terms of several measures of effectiveness, including reduction in station closed time, shorter queues, shorter station transit times, and reduced risk of collisions on the station entrance ramp (as estimated by reduction in number of times trucks must brake suddenly to avoid hitting the last truck in queue).

## **Results**

The two scenarios for the Seymour station with longer ramps did not produce significant improvements in any of the measures of effectiveness studied, except for hard deceleration by trucks on the station entrance ramp. Longer ramps take longer to fill up, but also take longer to empty once they are full, so there is little net reduction to station closing time. Moreover, since the queues are longer on the longer ramps, the time spent waiting in line by trucks is significantly greater.

Greater percentages of transponder-equipped trucks yield greater benefits. Each truck that does not have to enter the station not only saves time for itself but reduces the arrival rate within the station, the average queue length, the time spent in line by trucks in the queue, and the frequency of queue overflow. However, low market penetration (5% to 10%) is not sufficient to make significant improvements in the measures of effectiveness. It takes 40% to 50% of trucks with transponders to reduce congestion to minimal levels.

A WIM scale is very effective in reducing the number of trucks that must be weighed at the static scale. The majority of trucks are measured as weighing under the 65,000 threshold, even accounting for some error in the WIM scale measurement. The significant reduction in the number of trucks that have to wait in the queue leads to significant reductions in the average queue length, the time spent in line by trucks in the queue, and the frequency of queue overflow. The proposed dual static scale at the Lehi station was also very effective in reducing queue lengths and queue overflow.

## **Conclusions**

Westa has been shown to be a useful tool for analysis of weigh stations. It represents current conditions with a visual display that is easy to understand and with output statistics that are credible to station operators and state planners. It is capable of modeling each proposed change in facility, traffic level, or operating policy, and of quantifying the effects of the changes. Officials in each of the three states have declared that the Westa project has been helpful in analyzing alternatives and in presenting the results of the analysis to others.

Following publication of this report, the Westa program, program documentation, and user's guide will be made available on the World Wide Web. Since the program development and the pilot project were funded by the FHWA, the software and documentation are available at no charge.

The program may also be used for facilities other than weigh stations, such as toll plazas, safety inspection stations, and customs inspection stations at border crossings.

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# Introduction

## 1.1 General Description of the Problem

There are over 600 commercial vehicle inspection stations (weigh stations and ports of entry) in the United States. Nearly 160 million trucks are weighed and about 1 million vehicle/ driver safety inspections are conducted each year at these sites<sup>1</sup>.

Three inspection functions are performed at these inspection stations: vehicle weighing to determine whether a truck is over the legal weight limit, vehicle safety inspection, and driver credential inspection. The latter two inspections are performed for a small selected subset of trucks while those trucks are parked and not obstructing other truck traffic, but the first function (weighing) can cause large queues to form.

When the queue of trucks waiting to be weighed threatens to back up onto the mainline, the weigh station scales must be closed temporarily to further truck entry. When this happens, overweight and unsafe trucks may avoid inspection and enforcement. At some busy weigh stations, such as the three stations described in this report, this condition occurs regularly. Other weigh stations can handle current traffic loads but expect growth in truck traffic to overwhelm the current facilities. An additional problem caused by long queues is the lost time spent waiting in line by the majority of trucks that are of legal weight.

## 1.2 Westa Program

The Federal Highways Administration (FHWA) Joint Program Office (JPO) for Intelligent Transportation Systems (ITS) funded the development of the Westa simulation program by Mitretek Systems. Program development has also been supported by the FHWA Office of Motor Carriers (OMC) Size and Weight team. The name Westa is a contraction of “weigh station,” and the purpose of the program is to estimate the benefit of technological approaches to solving congestion problems at weigh stations and similar facilities.

Westa is a detailed simulation of truck, car, and other traffic around inspection stations. It is written in the C++ computer language and runs on most IBM-compatible personal computers. It does not depend on any other commercial software. A description of the approach and algorithms used in Westa is presented in section 2 of this paper. A more complete system description and documentation of input values is presented in the Westa Systems Description and User’s Guide<sup>2</sup>.

Following initial program development, the JPO and OMC desired to test the program in some real situations, to evaluate whether the model is capable of representing actual weigh station configurations and alternatives with sufficient accuracy and credibility to be of use to weigh station operators and planners. During January 1998, the JPO sent a letter to all state departments of transportation, offering to fund a Westa study of a weigh station. The following month, JPO, OMC, and Mitretek selected three states for pilot projects, based on responses from the eleven states that responded. The three states chosen were Indiana, South Dakota, and Arkansas. The criteria for selection were (a) immediacy of the problem at a weigh station, (b) availability of data for modeling the station, and (c) likelihood of the state being able to implement the required changes within the next few years. The

third requirement opens the possibility for follow-up analysis to assess the accuracy of Westa's predictions.

During the following year, Mitretek visited the sites, collected data from various sources, built and validated base case scenario models, built alternative scenarios, and analyzed the results. This report documents the studies of three congested weigh stations:

1. Seymour Weigh Station, Indiana
2. McCook Port of Entry, South Dakota
3. Lehi Weigh Station, Arkansas

Mitretek delivered a separate report for each state. This report is a combination of the three studies, eliminating duplicated material.

### 1.3 Reducing Overflow at the Seymour Weigh Station: Three Approaches

The first project studied three approaches for reducing the overflow of trucks at the Seymour, Indiana weigh station. Figure 1-1 indicates the location of the station on I-65 south of Indianapolis.

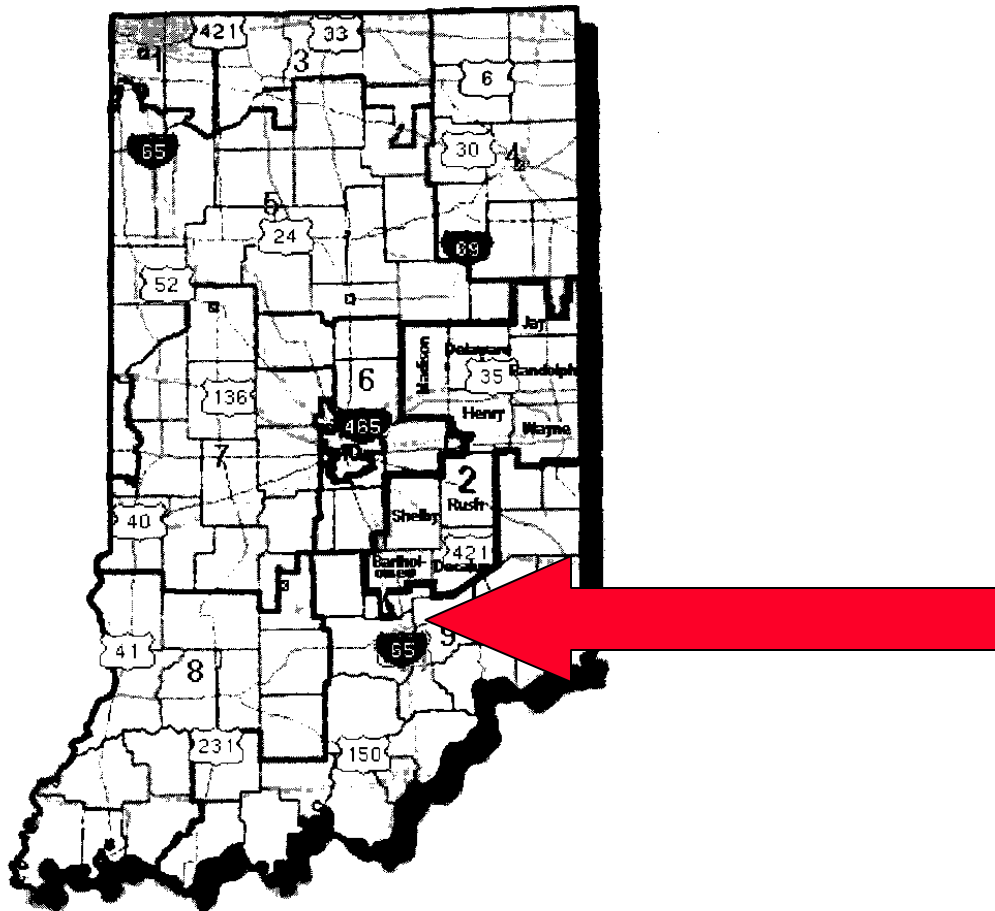


Figure 1-1. Location of the Seymour Weigh Station

The first two approaches reduce the number of trucks that must be weighed at the static scale, and thus reduce average queue sizes. Shorter queues save time for all trucks and reduce the chance of missing overweight trucks because of queue overflow. Both approaches can be classified as Commercial Vehicle Operations (CVO) ITS features. The third approach does not reduce average queue sizes, but lengthens the station entrance ramp to hold longer queues.

### **1.3.1 Vehicle Transponders and Sensing Equipment**

The first approach is the use of transponders on trucks and roadside devices capable of reading them at highway or ramp speeds. The study varies the percentage of trucks with transponders bearing the proper information for bypassing the weigh station. This capability could be implemented in the real world either by recording the truck's weight and safety information on the transponder, or by maintaining an on-line database, needing only the truck's Vehicle Identification Number (VIN) to be retrieved in real time. The notification to a truck that it may bypass the weigh station may be displayed on a Variable Message Sign (VMS) or in the truck's cab on a small display unit. The model does not distinguish among these implementation options, since they are functionally equivalent.

The Indiana Department of Transportation is considering participating in the Advantage I-75 Mainline Automated Clearance Program<sup>3</sup>. If Indiana weigh stations were equipped to read the same transponders, then equipped trucks traveling the I-75 corridor could also travel the I-65 corridor without requiring additional inspections.

### **1.3.2 Weigh-in-Motion Scale**

The second approach is to use a Weigh-in-Motion (WIM) scale to pre-screen the trucks<sup>4</sup>. The WIM scale may be on the mainline or on a low-speed lane within the weigh station. Trucks measuring less than a specified threshold are directed to remain on the highway (if mainline WIM) or proceed on a bypass lane directly back to the highway (if off-line WIM). Trucks measuring greater than the specified threshold are directed to proceed to the static scale. This study models an off-line WIM scale located within the station. This implementation is preferred by many weigh station operators because it is more accurate than high-speed WIM scales and because it gives them a chance to look quickly at each truck.

WIM scales are not considered as accurate as static scales, with standard deviations ranging from 3% to 8% of actual truck weight<sup>5</sup>. Therefore the threshold must be set lower than the legal limit to increase the probability that an overweight truck will be measured as being overweight. Necessarily, this means that some underweight trucks will also be directed to the static scales. Setting the threshold at any level greater than the weight of a half-full truck substantially reduces the number of trucks that must be weighed on the static scale.

There is enough space between the edge of I-65 and the Seymour station to construct a bypass lane within the station. However, the expense of building a bypass lane and the expense of installing and maintaining a WIM scale are not addressed in this report.

### **1.3.3 Longer Entrance Ramp**

The third approach is to lengthen the approach ramp. Longer ramps are able to hold more trucks before the queue threatens to overflow onto the highway. If trucks consistently arrive at the station at a greater rate than they can be weighed, a longer ramp will provide a benefit for only a brief time

before it too fills up. If the traffic surges are sporadic however, a longer ramp may provide the extra buffer capacity to handle temporary long queues.

The location of overpasses on either side of the Seymour station does not allow for very much additional ramp length. However, these bridges may be overhauled in the next several years, and may be re-designed to accommodate longer ramps from the station. The cost of constructing longer ramps is not addressed in this report.

#### **1.4 Study of the McCook Port of Entry Weigh Station**

The second project was a study of the current condition at the McCook Port of Entry weigh station and a replacement station proposed by South Dakota Department of Transportation (SDDOT). The replacement station would use a WIM scale within the station to pre-screen the trucks<sup>4</sup>. A low-speed WIM scale within the station is preferred by many weigh station operators to a high-speed WIM scale on the highway mainline because it is more accurate and because it gives them a chance to look quickly at each truck.

SDDOT and SDHP proposed using the WIM scale to check for axle weight violations as well as gross weight violations. Those trucks violating axle weight limitations and ten percent of the trucks exceeding gross weight limits but not axle weight limits would be sent to the static scale. The latter ten percent would be randomly chosen for permit checks. The remaining ninety percent of trucks over the gross weight threshold, and all trucks measured under the gross weight threshold, would be directed to proceed on a bypass lane directly back to the highway.

WIM scales are not considered as accurate as static scales, with standard deviations ranging from 3% to 8% of actual truck weight<sup>5</sup>. Therefore the threshold must be set lower than the legal limit to increase the probability that an overweight truck will be measured as being overweight. Necessarily, this means that some underweight trucks will also be directed to the static scales. Setting the threshold at any level greater than the weight of a half-full truck substantially reduces the number of trucks that must be weighed on the static scale.

Figures were not available defining the proportion of South Dakota trucks over gross weight that are also over axle weight limitations. Mitretek first assumed a lower bound figure of ten percent, and modeled the proposed new station with 20% of the trucks over the WIM threshold directed to the static scales (ten percent axle weight violations and ten percent random checks). Mitretek then modeled as a second alternate scenario the upper bound with all trucks over the WIM threshold directed to the static scales.

SDDOT also asked Mitretek to model the same scenarios with increased truck traffic, reflecting expected growth forecasted by Team 2000<sup>6</sup>. Mitretek ran each of the three scenarios with the current traffic load, and then with 120% of the current traffic load, and with 130% of the current traffic load.

Figure 1-2 shows the location on this station on Interstate I-29 near the southeastern border of the state.



# South Dakota

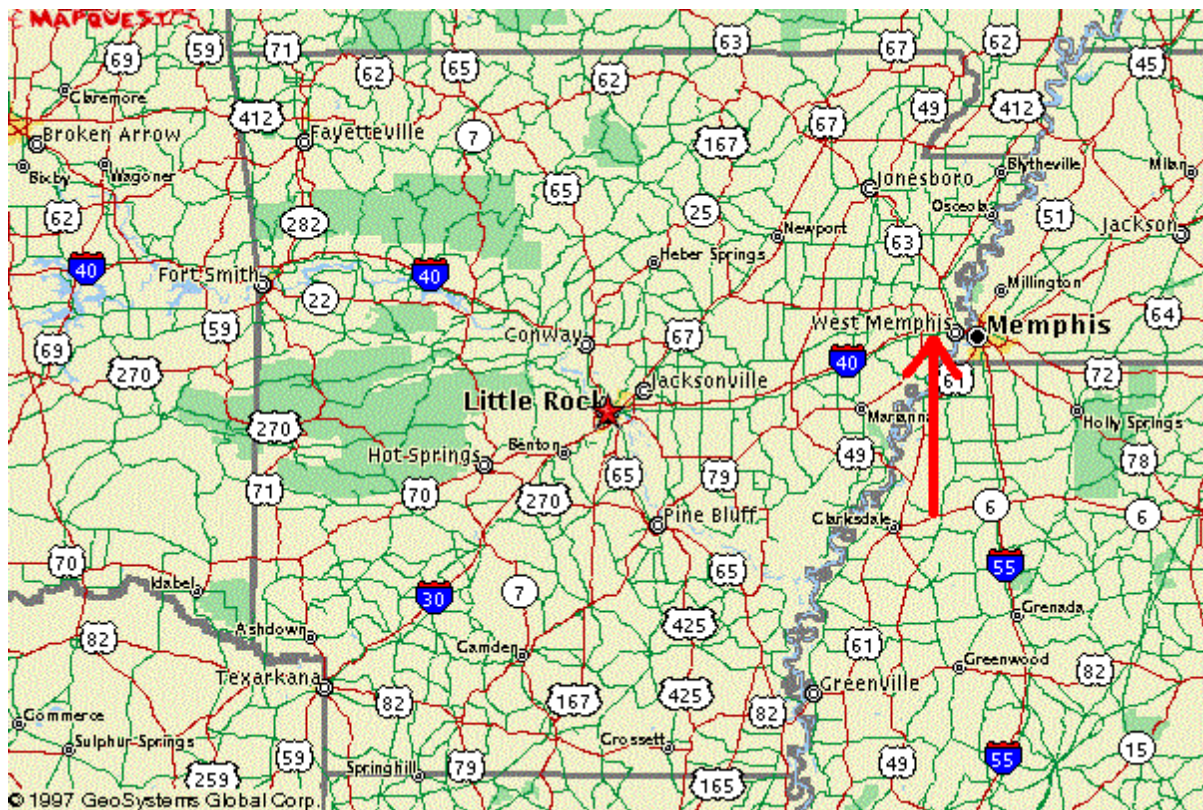


**Figure 1-2. Location of the McCook Port of Entry**

## **1.5 Study of the Lehi Weigh Station**

The third project studied the current condition (base case) at the Lehi, Arkansas weigh station and various alternate scenarios proposed by the Arkansas Highway and Transportation Department (AHTD). The first alternate scenario features dual static scales, doubling the weighing capacity of the station. The second alternate scenario features a high-speed WIM scale on the highway mainline. The high-speed WIM scale would check all trucks for violations of maximum axle weight, and compliant trucks with transponders would be given permission to bypass the station. Trucks without transponders and all trucks exceeding maximum axle weight must enter the station to be weighed. The third alternate scenario features a combination of the previous two features. Mitretek also modeled the base and three alternate scenarios with increased percentages of trucks with electronic transponders. The percentage of transponders ranged from the current levels of 12% up to 40%.

Figure 1-3 shows the location on this station on Interstate I-40 near the eastern border of the state.



**Figure 1-3 Location of Lehi Weigh Station**

## Section 2

# Description of the Westa Model

### 2.1 Overview of Westa

Westa (Weigh Station model) is a PC-based tool designed for modeling truck weigh stations on highways or any vehicle inspection or toll-collection station. It is a micro-level simulation program for evaluating operational performance under various traffic scenarios, inspection capabilities, and station configurations. It quantifies the effectiveness of advanced capabilities for (1) increasing enforcement of weight, safety, and customs regulations; (2) increasing vehicle throughput; and (3) reducing station queue lengths, delay to vehicles, and the time the entire station or components of the station are closed because of queue overflow. While Westa was originally developed to model trucks, it has been adapted to represent other vehicle types as well. Simulations run very quickly, producing animated graphics and writing statistics to permanent files. Westa is an object-oriented program written in the C++ computer language.

Westa simulates the behavior of each truck, car, or bus, from its creation at an origin, through each stage of its progress through the inspection or toll collection station and/or on the mainline, to the point where it leaves the simulation beyond the station. Vehicles may be routed depending on weight according to static or Weigh-in-Motion (WIM) scales or such user-defined characteristics as use of a pre-clearance transponder, preferred carrier or commuter status, safety status, or credential status.

Westa models inspection and toll collection facilities with a series of straight or curved one-lane links. Multiple lanes are modeled as parallel single lanes with defined rules for lane switching. Each vehicle moves along a series of links from an origin to a final destination. A link may branch forward to two others, allowing for multiple paths, and two links may merge into the same link. Upon arrival at a branching link, a vehicle is routed based upon its characteristics or the status of the links ahead. The user may define the combination of characteristics to be checked at each branch.

### 2.2 Vehicle Movement

Vehicle movement is calculated on the basis of a user-specified time-step value. Westa accepts time-step values as small as one-tenth of a second. Each vehicle moves according to its speed-dependent acceleration and deceleration abilities as well as those of the vehicles ahead of it. A vehicle's maximum acceleration rate decreases linearly with velocity, but its maximum deceleration rate is constant. Each vehicle attempts to accelerate to the maximum allowed speed for the link it is on, but decelerates for slower-moving vehicles ahead of it, a slower speed limit on the link ahead, or a required stop ahead. Vehicles will speed up or slow down as necessary for a merge.

Each vehicle has a maximum and a comfortable deceleration rate. If the user does not specify otherwise, Westa uses a default uniformly distributed maximum deceleration rate that ranges from 0.68g to 1.00g for cars and from 0.40g to 0.50g for trucks. Westa considers all simulated deceleration rates in excess of 0.30g for cars and 0.20g for trucks as hard braking, and reports this information as part of the traffic safety statistics. The comfortable deceleration rate defaults to 30 percent of the maximum value. The user may also specify maximum acceleration rates. The default maximum acceleration rate is generated from a uniform distribution with a range of 0.15g to 0.30g for cars and 0.06g to 0.12g for trucks.

When following another vehicle, a vehicle will keep a distance and speed such that if the vehicle ahead were to come to a stop at its maximum deceleration, the following vehicle would be able to stop with its preferred deceleration and avoid a collision. Only vehicles designated as being driven by aggressive drivers may exceed the speed limit on a link. No vehicle may move in reverse.

## 2.3 Vehicle Characteristics

When a vehicle is generated at an origin, the values of its characteristics or attributes are determined. Some characteristics are built into the model, but the user may define any other characteristics and the probability of occurrence as described below.

### 2.3.1 Vehicle Class

The first thing determined for a new vehicle is its vehicle class. Many other characteristics depend on the vehicle class. Westa recognizes the 13 vehicle classes defined by the FHWA. The following table defines the 13 classes. The proportion of vehicles of each class entering the simulation on each origin lane is defined in the input file (see section 3).

Class	Description
1	Motorcycles
2	Passenger Cars
3	2-axle 4-tire trucks (pickup trucks)
4	Buses
5	2-axle 6-tire single unit trucks
6	3-axle single unit trucks
7	4 or more axles, single unit trucks
8	4 or fewer axles, single trailer trucks
9	5 axles, single trailer trucks
10	6 or more axles, single trailer trucks
11	5 or fewer axles, multi-trailer trucks
12	6 axles, multi-trailer trucks
13	7 or more axles, multi-trailer trucks

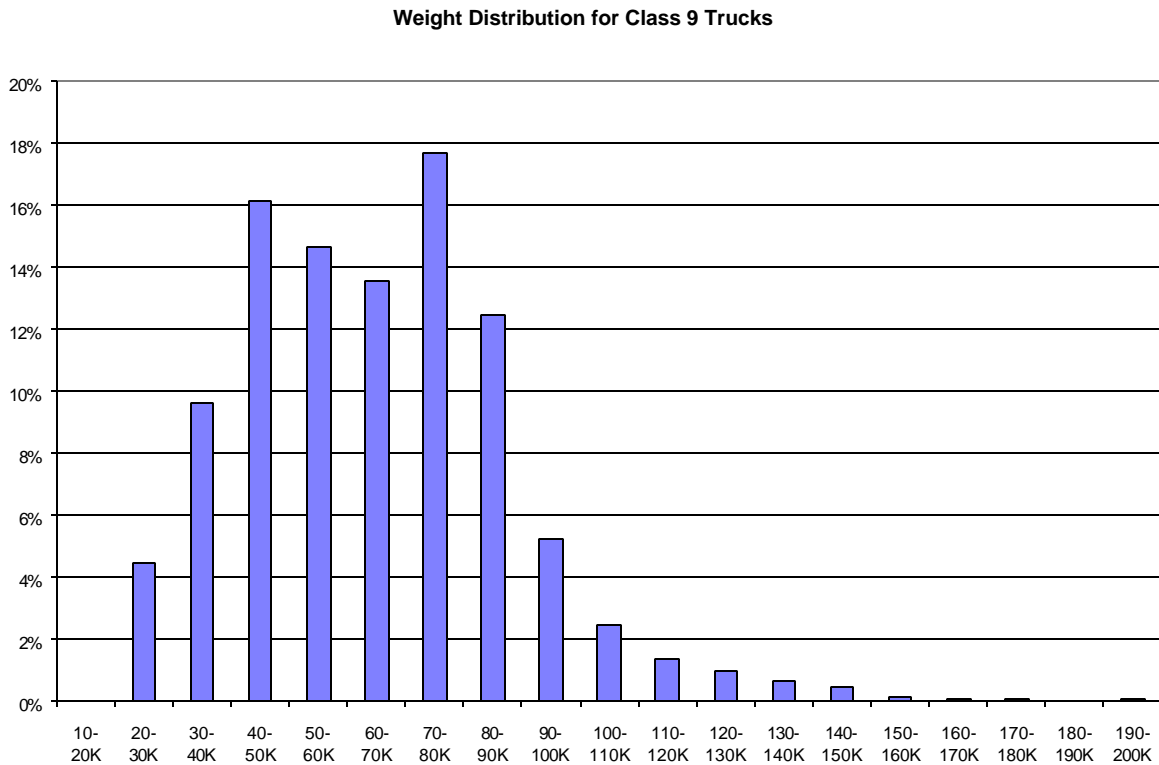
**Table 2-1. FHWA-Defined Vehicle Classes**

### 2.3.2 Built-in Vehicle Characteristics

The following characteristics are specified in the input file for each vehicle class. Mitretek has customized the default values to use data provided by the various state agencies, as described in sections 3 through 5.

- **Weight.** Given its vehicle class, a vehicle's weight (in pounds) is picked randomly, given minimum and maximum values and the percentage of vehicles falling into ten equally spaced bands between the minimum and maximum. For example, figure 2-1 below shows the distribution of weights for vehicle class 9 (5-axle trucks with single trailers) in Arkansas, obtained from data provided by

AHTD. A different distribution is used for each class. Automobile weights are chosen the same way, using specified weight distributions for vehicle class 2.



**Figure 2-1. Distribution of Weight for Vehicle Class 9**

- **Length.** Given its vehicle class, the length of a vehicle (in feet or meters) is picked randomly, given minimum and maximum values and the percentage of vehicles falling into ten equally spaced bands between the minimum and maximum. Automobile weights are chosen the same way, using specified length distributions for vehicle class 2.
- **Maximum acceleration rate.** This rate (in feet/sec<sup>2</sup> or meters/sec<sup>2</sup>) is randomly chosen from a uniform distribution between the specified minimum and maximum for the vehicle class. The default minimum is 0.15g for cars and 0.06g for trucks, and the default maximum of 0.30g for cars and 0.12g for trucks.
- **Maximum deceleration rate.** This rate (in feet/sec<sup>2</sup> or meters/sec<sup>2</sup>) is randomly chosen from a uniform distribution between the specified minimum and maximum for the vehicle class. The default minimum is 0.68g for cars and 0.40g for trucks, and the default maximum is 1.00g for cars and 0.50g for trucks.

### 2.3.3 User-Specified Characteristics

The user may specify any characteristic relevant to the study. Examples are presence of transponder, safety status, carrier status, customs status, hazardous materials (HAZMAT) status, type of violation, and driver credential status. A characteristic could be defined solely to predetermine whether a vehicle will turn left or right at a certain branch point. The value of each user-defined characteristic is either true or false. The user specifies in the control file the probability that the characteristic will be

true for each vehicle. That probability may depend on the value of previously defined characteristics. For example, the user may specify the correlation between trucks over gross weight and trucks exceeding maximum axle weight, or may specify that trucks owned by a “preferred” carrier are less likely to be pulled over for inspection than other trucks. These characteristics form the basis for routing vehicles at branch points. The value of these characteristics may be set or reset as the result of tests performed at branch points during the simulation. The service time for a vehicle at a branch point may also depend on a specified combination of its characteristics.

The vehicle characteristics defined for the three state models are described in Sections 3 through 5. The models also specify a characteristic named “car” so that cars may be displayed on the screen with a different color than trucks. For other purposes, cars are simply vehicle class 2.

## **2.4 Driver Characteristics**

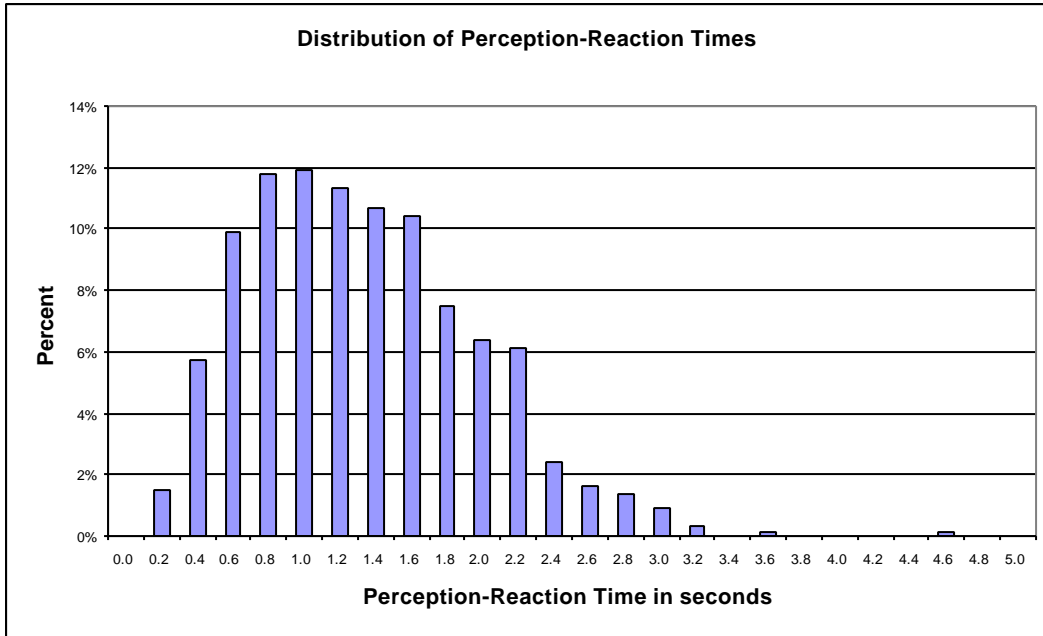
The driver-characteristics component of Westa provides a means of simulating variations in driver behavior, including speeding, aggression, and perception/reaction times. Simulation of these variations can help study traffic safety concerns such as the safety implications of merge and diverge maneuvers in the vicinity of the inspection facilities. Westa does not predict traffic crashes, but provides statistics on hard braking incidents that can be used as a surrogate for the level of risk exposure at inspection facilities. Westa’s safety module is most relevant as a planning decision support system. The user can test the viability of different operational scenarios, and make a decision on the preferred scenario based on the relative magnitude of simulated risk exposure (i.e., hard braking incidents). Westa accepts two primary sets of input data on driver attributes: aggressiveness and perception-reaction time.

### **2.4.1 Driver Aggressiveness**

Driver aggressiveness is a primary safety concern. Aggressive driving behaviors have been associated with a number of high-risk attributes, including the acceptance of short gaps or headway, sudden acceleration and deceleration, and/or speeding. In a Westa simulation, aggressive drivers travel up to 20% higher than the specified speed limit for each link. Aggressive drivers also require shorter headways when deciding whether to change lanes or decelerate for a slow-moving leader. That is because they anticipate that they and other drivers will decelerate at the maximum deceleration rate, while a normal driver will expect braking at a more comfortable deceleration rate. Westa’s default value for the proportion of aggressive drivers is 20 percent. This percentage is the same across all vehicle classes.

### **2.4.2 Driver Perception-Reaction Time**

Westa uses perception-reaction time (PRT) information in executing the vehicle-following logic described below. Westa uses a Weibull distribution to generate PRT values for individual drivers. The probability density function of the Weibull distribution is  $f(x) = k\lambda^{-k}x^{k-1}\exp(-x/\lambda)^{-k}$ ; where  $k$  and  $\lambda$  are non-negative shape and scale parameters, respectively, the mean  $\mu = \lambda/k\Gamma(1/k)$ , and  $\Gamma(k)$  = gamma function of  $k$ . The default values for  $\lambda$  and  $k$  parameters of the Weibull distribution are 1.35 seconds and 2.00 seconds, respectively. These parametric values of the Weibull distribution correspond to an average PRT value of 1.20 seconds. Figure 2-2 below illustrates the distribution of PRTs across drivers.



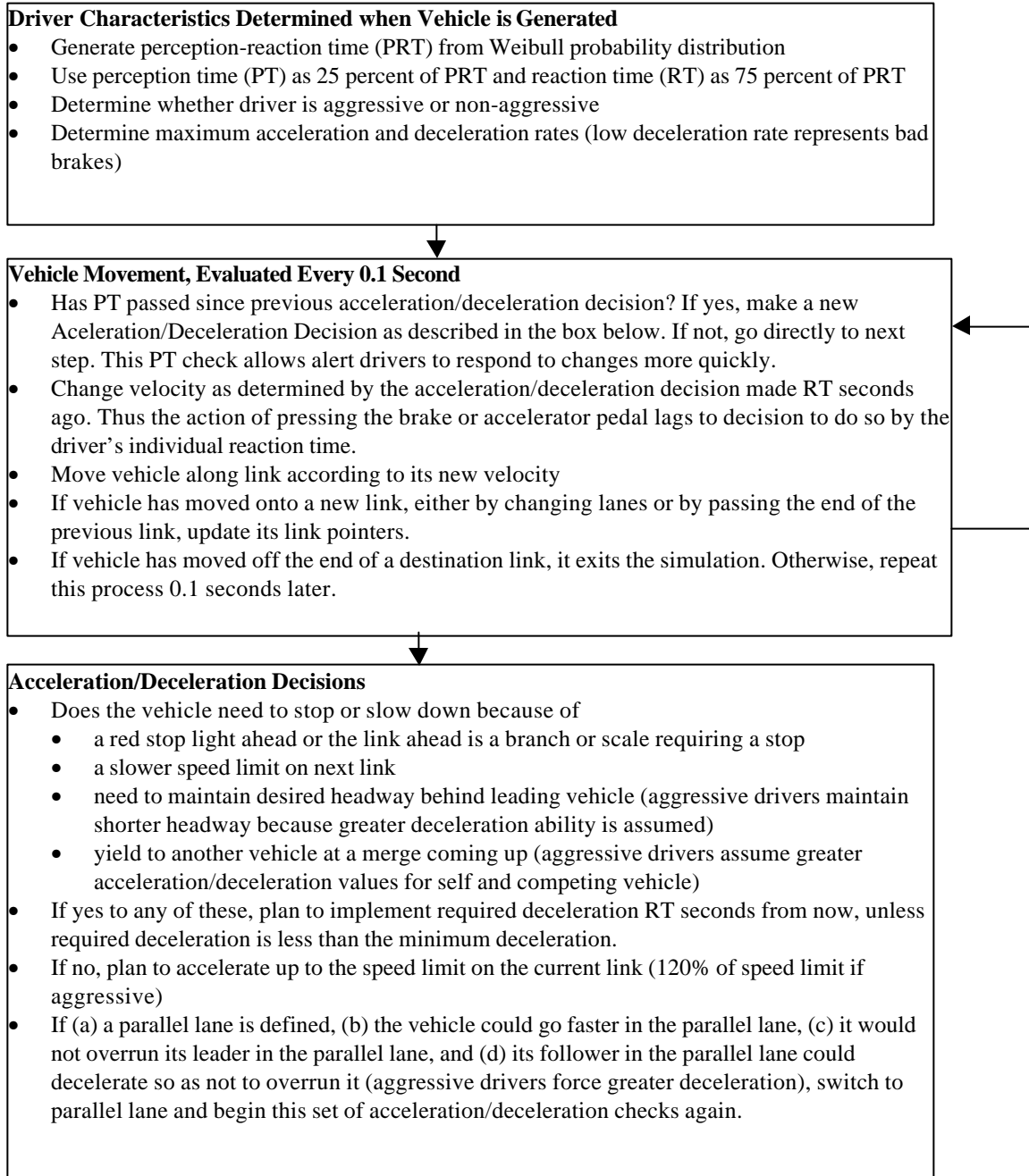
**Figure 2-2. Distribution of Driver Perception-Reaction Times**

### 2.4.3 Vehicle-Following Logic

Westa's vehicle-following logic governs drivers' decisions to change speed and to change lanes. The primary components of the logic include the gap acceptance principle of drivers during a merge or lane change maneuver and the spacing maintained between vehicles in the traffic stream. The size of the gap accepted during a merge or the spacing maintained in the traffic stream depends on whether a driver is aggressive or non-aggressive. A block diagram of the vehicle-following logic is shown in Figure 2-3.

Two safety regimes are assumed in the vehicle-following logic. The first safety regime, maximum acceleration for a merge or lane change maneuver and maximum deceleration for a stopping distance, is assumed for aggressive drivers. The second safety regime, comfortable acceleration for a merge and comfortable deceleration for a stopping distance, is assumed for non-aggressive drivers. The default values for maximum and minimum acceleration/deceleration rates for cars and trucks are documented in Section 3.2.





**Figure 2-3. Block Diagram of Vehicle-Following Logic**

## **2.5 Link Types and Traffic Signals**

Westa can model seven types of links: origin, transit, destination, scale, branch, parking lot, and building. The location and length of each link are determined by the x and y coordinates of its start and end points, specified in the input file. All links other than parking lots may be straight or curved. Westa can also represent two types of traffic signals: fixed timing plan and actuated. This section describes each link type and signal type.

### **2.5.1 Origin**

Vehicles are created on an origin link. Characteristics pertaining to each vehicle, such as weight, length, presence of transponder, safety status, and credential status, are determined at the origin based on vehicle information data specified in the control file. Any number of origin links may be specified. If more than origin is specified, the percentage of total traffic and the proportions of vehicle classes starting at each origin must be specified. An origin link has one next link and no previous links.

### **2.5.2 Transit**

A transit link functions as a one-lane highway, ramp queue, or any other type of link that does not have multiple exits. Each transit link has one next link and one or two previous links. If there are two previous links feeding into the transit link, one previous link must be specified as the yielding link. Vehicles coming from the yielding link must yield the right-of-way to those coming from the other link.

A transit link may be “closed” when the number of vehicles on it reaches a specified percentage of its capacity. A transit link will also close when the link ahead of it is closed. If there is a branch or scale link feeding into the closed link, the branch or scale link will abandon its switching function and will route vehicles to the non-closed alternative. If both alternatives are closed, the branch or scale link itself will close. When the number of vehicles on a closed link declines to the specified reopening threshold, the link is reopened and the previous branch link resumes its switching function.

### **2.5.3 Destination**

There may be more than one destination link. When a vehicle reaches the end of a destination link, it exits the simulation, its statistics are written to an output file, and on-screen statistics are updated. A destination link is the last link in a vehicle’s journey, unless the vehicle is placed out of service in a parking lot. Each destination link has one or two previous links and no next links. The same merging rules for previous links apply as for transit links. A destination link is never closed.

### **2.5.4 Branch**

A branch link has two next links and one or two previous links. The same merging rules for previous links apply as for transit links. When a vehicle arrives at a branch link, a test is performed, as a Boolean combination of any number of current vehicle characteristics and/or comparisons of current link queue lengths. If the outcome of the specified test is true, the vehicle is routed to the link specified by the test. If the outcome is false, the vehicle is routed to the other link. If a non-zero stop time is specified, each vehicle must come to a stop and must wait for a constant time, or a random amount of time drawn from an Erlang, normal, or uniform distribution with specified parameters. The wait time may be a function of vehicle characteristics. The presence of a transponder, the status of driver credentials, vehicle safety hazmat status, preferred or blacklisted carrier status, and bridge or axle weight violation status are examples of vehicle characteristics that can be defined by the user and

checked with a test. The value of one or more vehicle characteristics may be set or reset depending on the result of the test performed at the branch link. Branch links may be closed or open as described in the previous section.

#### **2.5.5 Scale**

A scale link is a special case of a branch link. When a vehicle arrives at a scale, a test is performed that compares the measured weight of the vehicle to the defined weight threshold for the scale. An error in the measurement is modeled by choosing the measured weight as a random variable from a normal distribution with the true weight as the average and a specified percentage of the true weight as the standard deviation. Vehicles that are measured above the scale's weight limit are routed to the link specified by the test, and those that are below the weight limit proceed to the other forward link. A static scale is modeled by assigning a non-zero stop time and a small or zero error term, while a WIM scale is modeled by assigning zero stop time and a larger error term. The time taken to perform the weighing is constant or a random number drawn from a normal, uniform, or Erlang distribution.

#### **2.5.6 Parking Lot**

A parking lot is a special case of a transit link. The user must specify a third corner point, so that the link is wide enough for diagonal parking. The user also specifies the number of parking spaces. If a vehicle enters an empty parking lot and no service time has been specified, it proceeds directly to the exit. If a waiting vehicle blocks the exit, the entering vehicle proceeds to the empty parking space nearest the exit, pulls into it, and waits. The lot may be treated as a first-in first-out queue, in which case the vehicle cannot pull out of its parking space and proceed to the exit until all vehicles that have entered the lot before the waiting vehicle have exited the lot. Alternatively, no queuing may be specified, in which case the time a vehicle waits does not depend on any other vehicle.

A parking lot is also a special case of a branch link. A test and a wait time may be specified. The wait time begins when the vehicle is first in line to leave the lot if queuing is specified, or as soon as it parks if queuing not specified. If the test results in the vehicle being assigned the characteristic named "OOS", the vehicle is placed out of service. The vehicle remains in the parking lot (occupying a parking space) until the end of the simulation, and its statistics are added into the running totals as if it had finished by leaving a destination link.

#### **2.5.7 Building**

A building is not a traveled link at all, but may be specified in the same manner as a link for convenience. It is displayed as a stationary yellow rectangle on the screen with a user-specified label. Examples are an office, an inspection shed, a tollbooth, or a simply a highlighted section of pavement such as a scale. It may overlay other links. It has no active role in the simulation.

#### **2.5.8 Fixed Signal**

A fixed signal turns red and green on a fixed cycle. The user specifies the length of the cycle in seconds, the number of seconds the light is green, and whether the simulation begins at the beginning of the red phase or the green phase. A traffic signal serving multiple approaches is modeled as multiple signals, one at the end of each link, with coordinated red and green phases.

### 2.5.9 Actuated Signal

An actuated signal is defined with pointers to one, two, or three other links. If there are any vehicles on any of the indicated links, the traffic signal is red. Otherwise, the signal is green. In other words, vehicles on the link with the actuated signal must stop until the other link is clear of traffic. An actuated signal may be used to enforce vehicle priority or merging patterns.

## 2.6 Use of Probability Distributions

Westa uses two independent streams of pseudo-random numbers during the course of the simulation. The first is used for determining vehicle characteristics and arrival times, and the second is used for determining weighing, inspection, toll-payment, and other activities involving delay times. The two streams are independent so that the arrival rate and characteristics of vehicles can be kept identical while station configuration and control strategies are varied.

The following sections describe the probability distributions used in Westa.

### 2.6.1 Exponential Arrival Rate

The time between the arrival of a vehicle at the origin and the arrival of the next vehicle is drawn from an exponential distribution whose average is the given interarrival rate. Figure 2-4 illustrates the probability of various interarrival times, given an average of 25 seconds. Interarrival times less than the average are most common, but occasional long gaps between arrivals are possible.

The density function for the exponential probability distribution is  $f(x) = 1/\alpha \exp(-x/\alpha)$ . The parameter  $\alpha$  of the exponential distribution is estimated from the empirical interarrival time data as  $\alpha = [\sum x]/n$ ; where  $x$  = interarrival time for individual vehicles, and  $n$  = number of vehicles observed in the analysis period. The value of the mean and variance for the exponential distribution is  $\alpha$ .

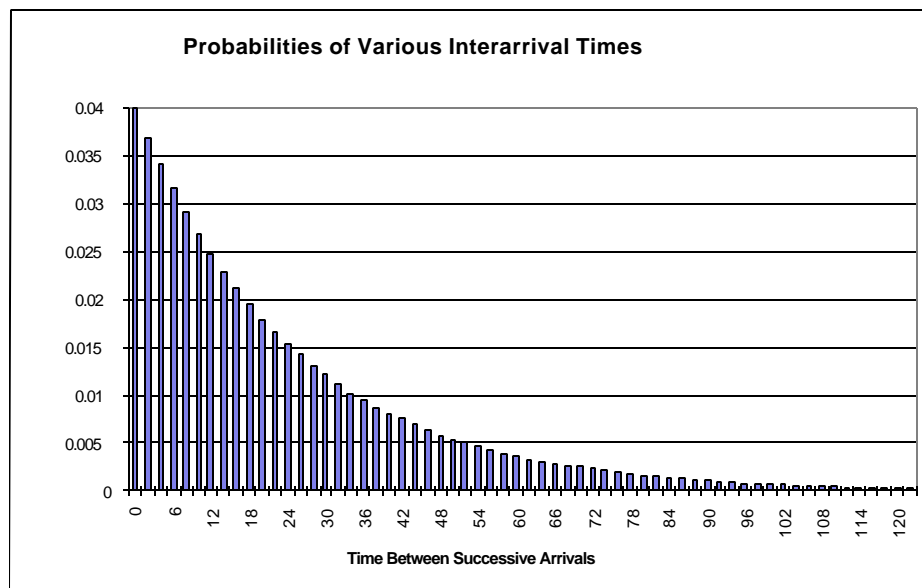


Figure 2-4. Sample Exponential Distribution

The user may specify different average interarrival times for different time periods. The transition between different arrival rates may be gradual or abrupt.

### 2.6.2 Uniform Distribution for Vehicle Attributes

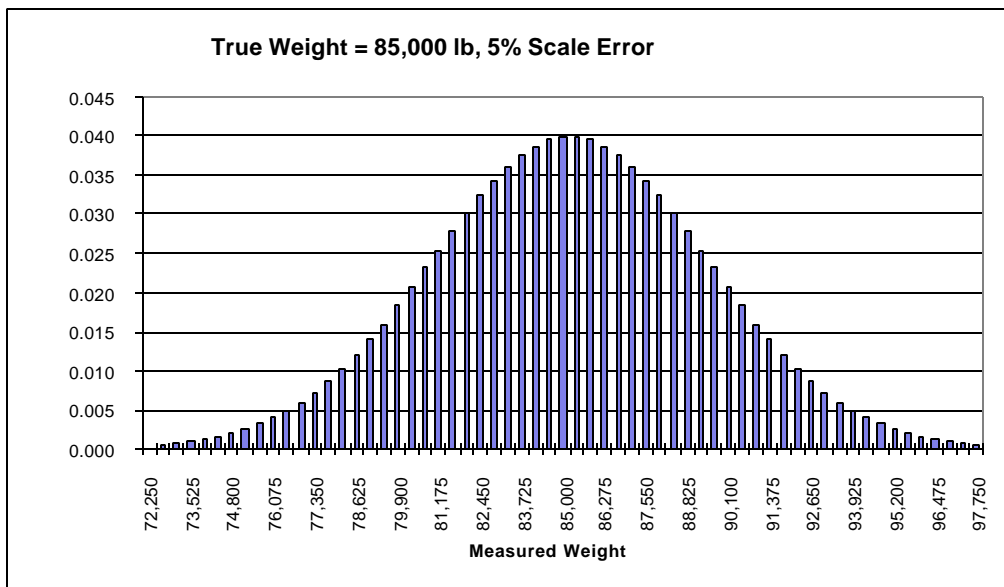
The user may specify that a certain percentage of vehicles have a certain attribute, or that a certain percentage of vehicles that possess a specified combination of previously defined attributes have the attribute. At the time each vehicle is created, a random number is drawn from a uniform distribution between 0 and 100 percent for each attribute to determine whether the vehicle has the attribute or not. For example, if the user specifies a 20% chance that a vehicle will have a transponder, whenever a vehicle is generated, a random draw of 20 or less means the vehicle has a transponder, and a draw of greater than 20 means the vehicle does not have a transponder.

The density function for the uniform probability distribution is  $f(x) = 1/b-a$ . The parameters  $a$  and  $b$  are the lower range value and upper range value, respectively. The mean and variance for the uniform distribution are  $(a+b)/2$  and  $(b-a)^2/12$ , respectively.

### 2.6.3 Normally Distributed Error for Weight Measurement

The operation of a scale is simulated using a random number from a normal distribution. The density function of the normal distribution is  $f(x) = [1/\sqrt{2\pi\sigma^2}]\exp(-(x-\mu)^2/2\sigma^2)$ . The average value  $\mu$  for the normal distribution is the true weight of the truck and the variance  $\sigma^2$  is chosen by the user to reflect the accuracy of the scale. For example, figure 2-5 below illustrates the probability distribution for the measured weight of a truck weighing 85,000 pounds, on a scale with an error of 5 percent.

Because of the error in measurement, a truck that is overweight may be weighed as being underweight or vice versa. For example, a truck with a weight of 75,000 pounds has a 99% chance of being measured over a threshold of 60,000 pounds, a 90% chance of measured over a threshold of 70,000 pounds, and a 10% chance of being measured over a threshold of 80,000 pounds.



**Figure 2-5. Probability of Measured Weight, Using a Normal Distribution**

#### 2.6.4 Normal, Uniform, Erlang or Constant Service Times

The time taken to weigh a truck on a scale, perform a safety inspection, write a ticket, or perform any other delay-causing activity is either a specified constant value or a random value drawn from a specified distribution. Random numbers may be drawn from (a) a normal distribution with a specified mean and standard deviation, (b) a uniform distribution between specified minimum and maximum values, or (c) an Erlang distribution with a given average value. Different probability distributions for service times may be specified for different categories of vehicles.

Values drawn from a normal distribution may have a negative value; if a negative value is drawn Westa replaces it with 0.01 times the mean. If the user does not have a large data set on the service times that can be used to select a reasonable probability distribution model, the use of a uniform distribution requiring only the minimum and maximum service-times is recommended.

The probability density function for the Erlang distribution is  $f(x) = (\lambda k)^k x^{k-1} \exp(-\lambda k x) / k-1!$ ; where  $\lambda = 1/\mu$ ,  $\mu$  = mean value of  $x$ , and  $k$  = shape parameter and is a positive integer. Westa uses the Erlang distribution with shape parameter  $k=4$ , since that value has been found to reflect the observed distribution of service times very well<sup>5</sup>. The figure below illustrates the probability of various truck-weighing times generated from the Erlang distribution for  $\mu = 25$  seconds.

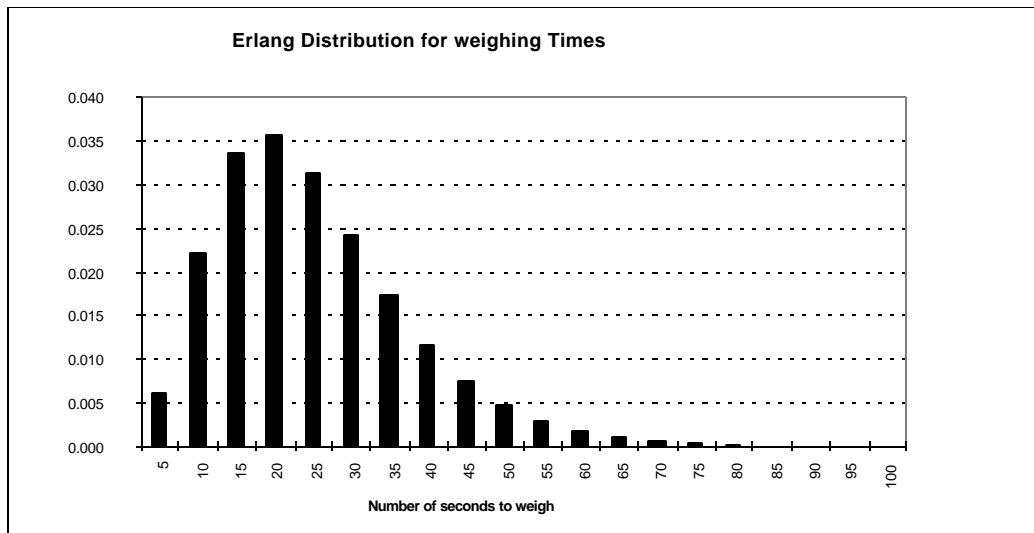


Figure 2-6. Probability of Weighing Times Using an Erlang Distribution

#### 2.6.5 Weibull Distribution of Perception/Reaction Time

The use of the Weibull distribution to represent driver perception-reaction times is presented in section 2.4 and illustrated in figure 2-2. This distribution has been found to be a good match of empirical data on perception-reaction times.



## Section 3

# Representation of the Seymour Weigh Station Scenarios

This section documents the input files defining the Seymour weigh station base case scenario and alternate scenarios. Section 3.1 documents how the base case scenario was constructed using data defining current station design and operation. Section 3.2 describes the changes made to the data file to represent an entrance ramp longer by 1000 feet or by 2000 feet. Section 3.3 describes the changes made to represent 5% to 50% of the trucks bypassing the station with transponders. Section 3.4 describes how a low-speed WIM scale with a threshold of 65,000 pounds was modeled. Section 3.5 describes how all the previously-described scenarios were run again with the level of traffic set at 80% of the base case scenario. Section 3.6 describes how the WIM scenario was varied, with a threshold of 75,000 pounds and with arrival rates at 120% and 140% of the base case arrival rate. Table 3-1 shows the scenarios used for the analysis.

Arrival Rate	Base Case	Ramp length		Transponder Usage						WIM threshold	
		+1000	+2000	5%	10%	20%	30%	40%	50%	65,000	75,000
Base	x	x	x	x	x	x	x	x	x	x	x
80%	x	x	x	x	x	x	x	x	x	x	
120%										x	x
140%										x	x

**Table 3-1. Scenarios Modeled**

### 3.1 Base Case Scenario

For each value or set of values, the source of the information is given. The lines of the input file are shown in bold Courier font, and the commentary follows in Times New Roman font. Any characters following the pound sign (#) in the input file are treated as comments. The complete input file is presented in Appendix A.

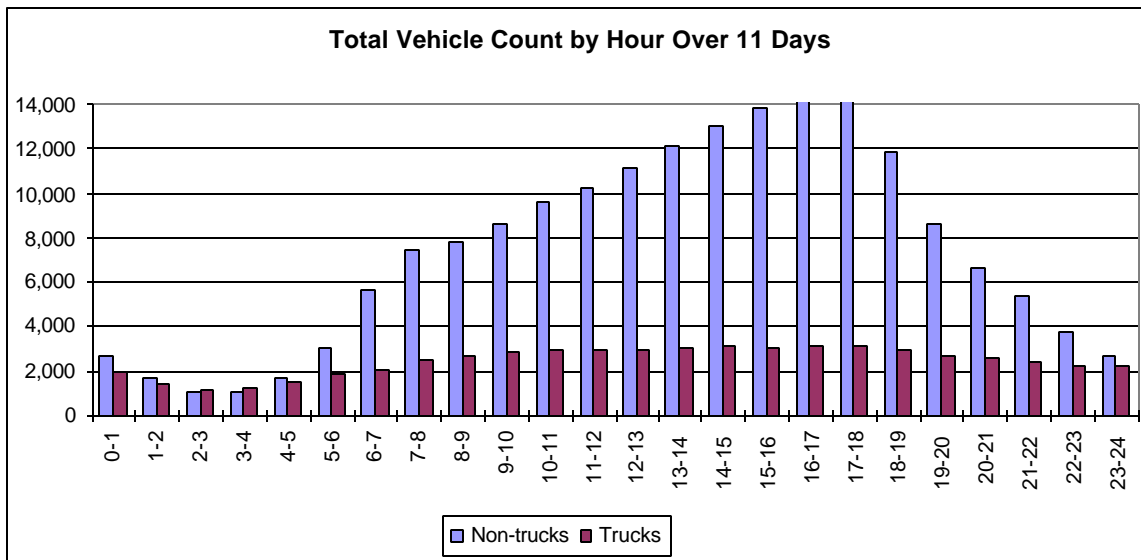
#### **Seymour, Indiana Base Case Scenario**

The scenario name is displayed at the top of the screen and included in the output files.

**runLength: 120 # run for two hours, 3-5 p.m. (peak period)**

The peak period was selected from hourly data from the Edinburgh Strategic Highways Research Program (SHRP) site, north of the Seymour station. Figure 3-1 shows the average hourly truck traffic recorded at the Edinburgh site between April 5, 1998 and April 16, 1998. It is interesting to note that trucks and cars exhibit the same daily pattern (lowest during the night and highest in the afternoon), but the difference is much greater for cars than for trucks. Truck traffic remains nearly constant from 10 a.m. through 10 p.m. However, the highest average values occur between 3 p.m. and 5 p.m. Mitretek modeled a constant arrival rate over a 2-hour period.





**Figure 3-1. Traffic on Northbound I-65 by Hour of Day**

```
randomSeed_truck: 241
randomSeed_link: 47
```

These random seeds initialize the random number generators for vehicle generation and weighing/inspection times. The numbers here were used for the first iteration. Mitretek ran each scenario ten times with a different set of random seeds for each iteration, and averaged the results together for the results presented in Section 6.

```
avgCreatTime: 2.56 # (sec.)
```

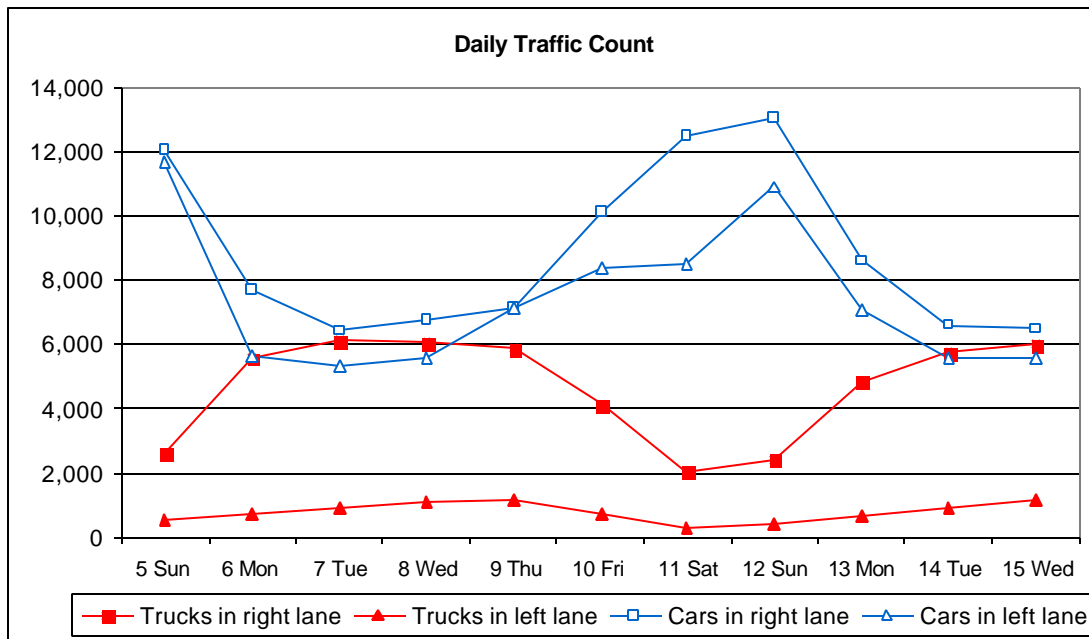
A vehicle is generated every 2.56 seconds on the average. The arrival rate of 1406 vehicles per hour was derived by Mitretek from the April Site Summary Report produced by INDOT using data collected by the SHRP facility at Edinburgh. Mitretek observed that the day of the week with the greatest number of trucks is Wednesday (see figure 3-2) while non-truck traffic is greatest on the weekends. Mitretek also noted that on a daily basis, truck traffic is greatest between 2 p.m. and 6 p.m. (see figure 3-3), with very little change during this peak period. Mitretek multiplied the truck and non-truck arrival rate for Wednesdays by the percent of truck and non-truck arrivals during the hour from 3 p.m. to 4 p.m. to arrive at 1406 vehicles per hour. This is the hour when there is the greatest number of trucks on the road – not the hour with the greatest total traffic. Section 3.5 describes a set of scenarios with a lower traffic demand.

```
maxWt: 80000 # <- maxWt for static scales
```

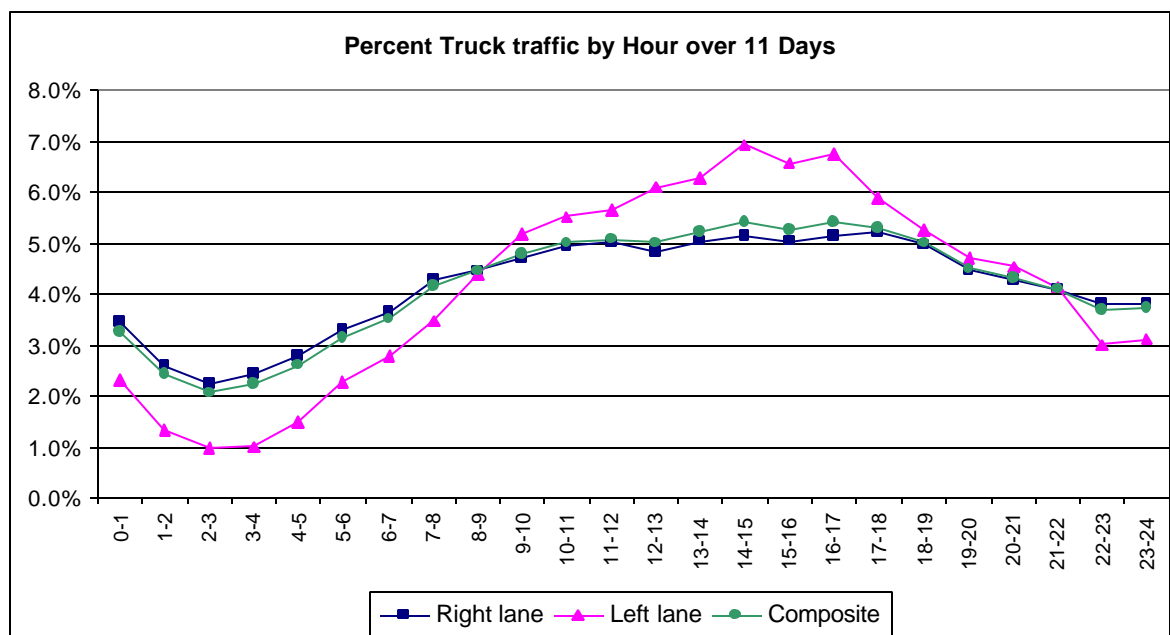
The maximum legal weight for trucks without a special permit is set at 80,000 pounds per Indiana regulations. Trucks weighing more than 80,000 pounds are considered overweight and are sent to the parking lot for a citation or permit check.

```
TimeStep .1
```

The size of the time step was reduced from one second to 0.1 second to enable detailed modeling of vehicle response to potentially hazardous situations. Driver perception-reaction times vary from 0.8 to 2.4 seconds, and vehicles have a corresponding lag in their behavior. Time steps as small as 0.1 seconds are required to model the effects of these different perception-reaction times.



**Figure 3-2. Northbound I-65 Traffic by Lane and Day of Week**



**Figure 3-3. Percentage of Daily Truck Traffic Occurring Each Hour**

#### [TruckInfo]

The following groupings define the distribution of length, weight, and acceleration/ deceleration characteristics for vehicles in each FHWA class. When values for any of these variables are not specified for a class, Westa uses values for the preceding class.

#### Class 2 Cars

**maxAccRange:** 2.8 6.3 .009 # (mi/hr/sec)

The maximum acceleration rate for each car is chosen from a uniform distribution between 2.8 and 6.3 mph per second. These values reflect the range of maximum acceleration capabilities for passenger cars reported in the Road Test Digest of Car and Driver magazine. Those acceleration figures are divided by two since the maximum acceleration used on a freeway is less than the maximum value on a test track. The value of 0.009 indicates that the maximum acceleration rate declines at .009 times the current speed (the faster a car is going, the smaller is its maximum acceleration).

**maxDecRange:** 17.3 20.7 .30 # (mi/hr/sec)

The maximum deceleration rate for each car is chosen from a uniform distribution between 17.3 to 20.7 mph per second. These values are the weighted averages plus and minus two standard deviations for maximum deceleration rates for passenger cars published in Consumer Reports magazine. The value of 0.3 indicates that the normal (comfortable) rate of deceleration is 0.3 times the maximum rate.

**weightRange:** 0 6000 # (lbs)

**weightDistrib:** 0.0 0.0 4.1 9.9 31.4 27.3 14.9 6.6 4.1 1.7 # (%)

The minimum and maximum weights serve as end points for the weight distribution. The weight range is divided into ten bins of equal size between the minimum and maximum value, and the percentages give the percent of cars in each bin. In this case, the bin size is 600 pounds. The values of weight distribution for cars reflect the weight range of new cars reported in Consumer Reports magazine. The weight of cars is irrelevant to the Seymour model in any case.

**lengthRange:** 10 20 # (ft)

**lengthDistrib:** 0.0 0.0 1.7 7.4 19.0 28.9 27.3 10.7 5.0 0.0 # %

The minimum and maximum lengths serve as end points for the weight distribution. The length range is divided into ten bins of equal size between the minimum and maximum value, and the percentages give the percent of cars in each bin. In this case, the bin size is 1 foot. The values of length distribution for cars reflect the length range of new cars reported in the March 1998 Consumer Reports magazine.

#### Class 3 2-axle 4-tire (Pickup trucks)

**maxDecRange:** 16.8 18.6 .30 # (mi/hr/sec)

The maximum deceleration rate for light trucks ranges from 16.8 to 18.6 mph per second. These values are the weighted averages plus and minus two standard deviations for maximum deceleration rates for light trucks published in Consumer Reports magazine. The value of 0.3 indicates that the normal (comfortable) rate of deceleration is 0.3 times the maximum rate.

**lengthDistrib:** 0.0 0.0 96.2 0.0 0.2 1.5 1.9 0.3 0.0

The length distribution for this class and for all truck classes was supplied by the South Dakota Department of Transportation (SDDOT). Mitretek assumed that the distribution of truck length for FHWA-defined vehicle classes is the same in Indiana as in South Dakota, so the same values were

used. Since the maximum and minimum lengths are not specified, the values for the previous class are used. Similarly, since the acceleration and weight characteristics of class 3 trucks are not specified, the values for cars are used. The weight of pickup trucks is irrelevant to the model in any case since they are not inspected.

#### Class 4 Buses

maxDecRange: 16.8 18.6 .30  
lengthRange: 30 40  
lengthDistrib: 0.0 0.0 96.2 0.0 0.2 1.5 1.9 0.3 0.0

The same deceleration characteristics were used for buses as for small trucks. The distribution of bus lengths came from SDDOT. Bus characteristics are not significant to the Seymour model since they are not inspected.

#### Class 5 2-axle 6-tire single units

The performance characteristics of class 5 trucks were assumed to be the same as for light trucks so they are not specified.

weightRange: 0 100000  
weightDistrib: 59.6 32.4 7.4 0.5 0.0 0.0 0.0 0.0 0.0 0.0

The weight distribution for this and all truck classes was taken from the Class by Gross Vehicle Weight Report produced by INDOT from data collected by the Edinburgh SHRP site. Table 3-2 shows the weight distribution for each class.

	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
0-10K	59.6%	0.3%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
10-20K	32.4%	40.3%	0.2%	5.7%	1.5%	0.3%	0.0%	0.0%	0.0%
20-30K	7.4%	32.9%	1.6%	27.3%	6.9%	3.1%	0.4%	0.0%	0.0%
30-40K	0.5%	13.6%	2.9%	36.1%	16.3%	14.4%	5.6%	5.8%	2.0%
40-50K	0.0%	9.0%	7.1%	22.9%	15.2%	14.6%	9.2%	12.4%	2.0%
50-60K	0.0%	2.6%	9.1%	7.5%	16.1%	10.3%	21.5%	18.2%	7.8%
60-70K	0.0%	1.1%	55.5%	0.4%	16.0%	11.5%	38.9%	31.4%	3.9%
70-80K	0.0%	0.2%	22.7%	0.0%	24.2%	18.8%	22.9%	26.1%	3.9%
80-90K	0.0%	0.0%	0.7%	0.0%	3.8%	14.6%	1.5%	5.0%	17.6%
>90K	0.0%	0.0%	0.2%	0.0%	0.0%	12.3%	0.0%	1.1%	62.7%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

**Table 3-2. Distribution of Truck Weights by FHWA Class**

lengthRange: 0 50 # (ft)  
lengthDistrib: 0.0 2.4 64.1 23.6 9.9 0.0 0.0 0.0 0.0 0.0

The length distribution for this class and for all truck classes was supplied by SDDOT.

#### Class 6 3-axle single units

maxAccRange: 1.3 2.6 .009 # (mi/hr/sec)

The maximum acceleration rate for each large truck (class 6 and above) is chosen from a uniform distribution between 1.3 and 2.6 mph per second. These values range around the value of .1g (2.2 mph) considered good acceleration for a loaded truck. The value of 0.009 indicates that the maximum

acceleration rate declines at .009 times the current speed (the faster a truck is going, the smaller is its maximum acceleration).

maxDecRange: 8.2 10.9 .30 # (mi/hr/sec)

The maximum deceleration rate for trucks ranges from 8.2 to 10.9 mph per second (.37g to .5g). The upper value was supplied by data in the American Trucking Association library. The lower value was based on the assumption that some trucks will have less than optimal brakes. The value of 0.3 indicates that the normal (comfortable) rate of deceleration is 0.3 times the maximum rate.

weightRange: 0 100000 # (lbs)

weightDistrib: 0.3 40.3 32.9 13.6 9.0 2.6 1.1 0.2 0.0 0.0 # (lbs)

The weight distribution for this and all truck classes was taken from the Class by Gross Vehicle Weight Report produced by INDOT from data collected by the Edinburgh SHRP site.

lengthRange: 0 50

lengthDistrib: 0.0 0.0 0.8 18.7 72.3 8.2 0.0 0.0 0.0 0.0 # %

The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 7 4 or more axles, single unit

weightRange: 0 100000

weightDistrib: 0.0 0.2 1.6 2.9 7.1 9.1 55.5 22.7 0.7 0.2 # (%)

The weight distribution for this and all truck classes was taken from the Class by Gross Vehicle Weight Report produced by INDOT from data collected by the Edinburgh SHRP site.

lengthRange: 0 50

lengthDistrib: 0.0 0.0 0.0 11.5 50.0 34.6 3.8 0.0 0.0 0.0 # %

The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 8 4 or fewer axles, single unit

weightRange: 0 100000

weightDistrib: 0.1 5.7 27.3 36.1 22.9 7.5 0.4 0.0 0.0 0.0

The weight distribution for this and all truck classes was taken from the Class by Gross Vehicle Weight Report produced by INDOT from data collected by the Edinburgh SHRP site.

lengthRange: 20 70 # (ft)

lengthDistrib: 0.0 6.8 22.4 35.1 16.4 7.4 6.5 4.2 1.1 0.0 # %

The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 9 5-axle, single trailer

weightRange: 0 100000

weightDistrib: 0.0 1.5 6.9 16.3 15.2 16.1 16.0 24.2 3.8 0.0

The weight distribution for this and all truck classes was taken from the Class by Gross Vehicle Weight Report produced by INDOT from data collected by the Edinburgh SHRP site.

lengthRange: 35 85

lengthDistrib: 0.2 0.6 2.1 10.0 37.1 46.0 3.9 0.2 0.0 0.0 # %

The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 10 6 or more axles, single trailer

weightRange: 0 100000

weightDistrib: 0.0 0.3 3.1 14.4 14.6 10.3 11.5 18.8 14.6 12.3 # (%)



The weight distribution for this and all truck classes was taken from the Class by Gross Vehicle Weight Report produced by INDOT from data collected by the Edinburgh SHRP site.

```
lengthRange:      20  90
lengthDistrib:  0.0  0.0  0.9  8.8 31.0 27.9 27.4  3.5  0.4  0.0  # %
The length distribution for this class and for all truck classes was supplied by SDDOT.
```

```
Class 11  1.1 % 5 or fewer axles, multi-trailer
weightRange:      0  100000
weightDistrib:  0.0  0.0  0.4  5.6  9.2 21.5 38.9 22.9  1.5  0.0 # (%)
The weight distribution for this and all truck classes was taken from the Class by Gross Vehicle
Weight Report produced by INDOT from data collected by the Edinburgh SHRP site.
```

```
lengthRange:      20  90#
lengthDistrib:   0.0  0.0  0.9  8.8 31.0 27.9 27.4  3.5  0.4  0.0  # %
The length distribution for this class and for all truck classes was supplied by SDDOT.
```

```
Class 12  6 axles, multi-trailer
weightRange:      0  100000
weightDistrib:  0.0  0.0  0.0  5.8 12.4 18.2 31.4 26.1  5.0  1.1 # (%)
The weight distribution for this and all truck classes was taken from the Class by Gross Vehicle
Weight Report produced by INDOT from data collected by the Edinburgh SHRP site.
```

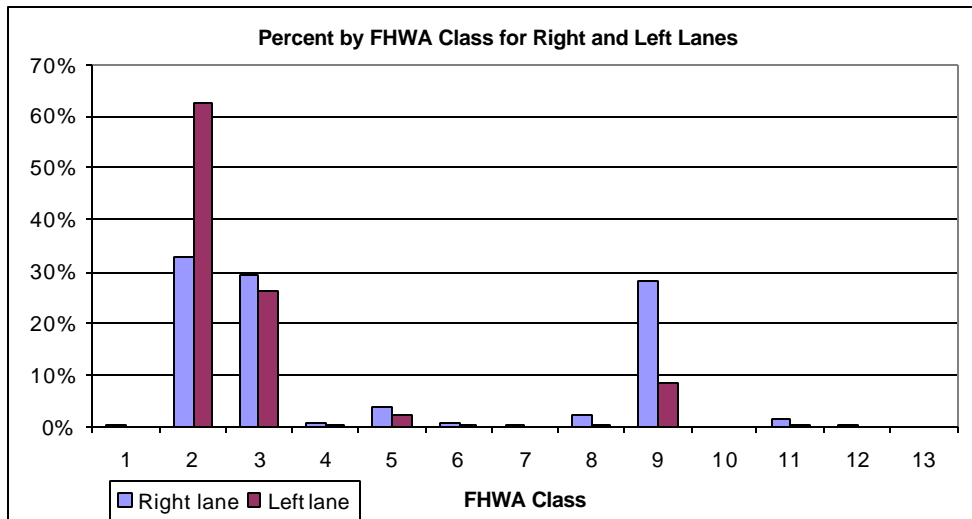
```
lengthDistrib:  0.0  0.0  0.0  0.0  0.0  0.0 26.4 36.8 36.8  0.0  # %
The length distribution for this class and for all truck classes was supplied by SDDOT.
```

```
Class 13  7 or more axles, multi-trailer
weightRange:      0  100000
weightDistrib:  0.0  0.0  0.0  2.0  2.0  7.8  3.9  3.9 17.6 62.7 # (%)
The weight distribution for this and all truck classes was taken from the Class by Gross Vehicle
Weight Report produced by INDOT from data collected by the Edinburgh SHRP site.
```

```
lengthDistrib:  0.0  0.0  0.0  0.0  0.0  0.0 26.4 36.8 36.8  0.0
The length distribution for this class and for all truck classes was supplied by SDDOT.
```

```
ClassDistribution 2 origins
Link  c1    c2    c3    c4    c5    c6    c7    c8    c9    c10   c11   c12   c13
  11  0.0  33.3  29.0   0.6   3.8   0.7   0.3   2.4  28.1   0.1   1.5   0.2   0.0
   1  0.0  62.6  26.0   0.2   1.9   0.4   0.0   0.2   8.5   0.0   0.2   0.0   0.0
```

Link 1 and link 11 are the two origin links, where vehicles enter the simulation. Link 1 represents the left lane of Interstate I-65 and link 11 is the right lane. These lines in the input file specify the percentage of each vehicle class to enter the simulation on each link. The percentage of each class was taken from the 4 p.m. data from the Edinburgh WIM site during April 1998 divided by the total number of vehicles recorded during those months. Unclassified vehicles were allocated proportionately to the 13 classes. Figure 3-4 shows the percentage of each vehicle class. The model treats classes 1 through 4 like cars, because they are not required to enter the weigh station.



**Figure 3-4. Distribution of Vehicle Types by Lane on Northbound I-65**

#### [Attributes]

Each attribute (also called a characteristic) of a vehicle is determined at the time it enters the simulation. Some attributes are given other values during the simulation as a result of a test. The probability of each characteristic being set to true is specified. The probability may depend on the value of previously set attributes. The cab and/or trailer of a vehicle may be displayed in a certain color to indicate that a certain attribute is true. Attributes need not be defined in numerical order, and there may be gaps in the sequence of attribute numbers.

#	name	cab color	trailer color	%	expr	%	expr
#	----	-----	-----	---	-----	---	-----
1	"car"	yellow	yellow	100	{ c2 }		

Cars are displayed in yellow. 100% of the vehicles in class 2 are designated as cars.

2	"truck"	default	default	100	{ ( not c2 ) and ( not c3 ) and ( not c4 ) }		
---	---------	---------	---------	-----	--	--	--

Trucks are normally displayed with the default color (blue). If the vehicle is not class 2, class 3, or class 4, there is a 100% chance that the vehicle will be a truck (i.e. all vehicles that are not cars, pickup trucks, or buses are trucks). Pickup trucks (class 3) and buses (class 4) are not treated like trucks since they are not required to stop for inspection.

3	"overweight"	default	lightred		owt { }		
---	--------------	---------	----------	--	---------	--	--

This attribute is true if the vehicle is overweight (over 80,000 pounds). The special keyword "owt" indicates that this attribute is set by comparing the weight to the limit, rather than by drawing a new random value. Overweight trucks are displayed on the computer screen with red trailers.

4	"safety check"	default	black	2	{ 2 }		
---	----------------	---------	-------	---	-------	--	--

If attribute 2 is true (the vehicle is a truck), there is a 2% chance the vehicle will be pulled over for a safety check. This percentage was the percentage of trucks pulled over for safety reasons as reported by South Dakota (this data was not available for Indiana). These trucks are displayed with black trailers.

5 "credential check" lightred default 4 { 2 }

If attribute 2 is true (the vehicle is a truck), there is a 4% chance the vehicle will be checked for credentials or logbook violations. This percentage was the percentage of trucks pulled over for credential checks as reported by South Dakota (this data was not available for Indiana). Trucks suspected of credentials or logbook problems are displayed with red cabs (suggesting the problem is with the driver, not the cargo).

6 "weighed" default default 0 { }

This attribute is set to true when the truck is weighed on the static scale (see test 6 below). It starts out set to false for all vehicles. It is defined simply so that the model can report the number of trucks to be weighed on the static scale.

7 "fixable" default default 100 { 3 } 100 { 5 } 90 { 4 }

100% of the trucks with weight (attribute 3) or credential problems (attribute 5) are considered "fixable" in that they are allowed back on the highway after a short time. 90% of the trucks with safety problems (attribute 4) are allowed to leave after the problem is fixed or noted. However, 10% of the unsafe trucks are placed out of service for the remainder of the simulation. These percentages come from data recorded at the McCook, South Dakota station over two days in June, where one unsafe truck was effectively placed out of service each day out of 9 or 10 unsafe trucks. Data from Indiana was not available.

8 "2nd try okay" lightblue lightblue 0 { }

Initially all vehicles have this attribute set to false. However, the vehicles that have been pulled into the parking lot and then released need a way to get past the inspection the second time. Therefore trucks leaving the parking lot have this attribute set to true, so they will not be pulled into the lot again (see test 4). Similarly, their color is restored to blue from whatever color it was to indicate that it may proceed back to the highway.

9 "OOS" black black 0 { }

Initially all vehicles have this attribute set to false. However, the trucks that are not fixable (10% of the unsafe trucks) are placed "out of service" and have this attribute set to true after inspection. They are displayed as all black, and they never leave the parking lot.

10 "bypassed" default white 0 { }

This attribute is designed to reflect the operation of the Seymour station where trucks are bypassed if the ramp is full. When the ramp is full, the "station closed" sign is turned on, and all trucks are permitted to bypass the weigh station. These trucks have attribute 10 set to true (see test 7 below) and are displayed with white trailers. This attribute is also set to true for trucks with transponders that bypass the station.

11 "bypass overwt" default white 0 { }

This attribute is set to true when an overweight truck bypasses the station (see test 8 below). It is defined simply so that the model can report the number of such trucks.

12 "legal in station" default default 0 { }

This attribute is set to true when a truck of legal weight with no credential or safety problems enters the weigh station (see test 9 below). It is defined so that statistics on the average station transit time for these trucks can be computed and displayed. Overweight trucks and trucks with credential or

safety inspections spend much longer in the simulation. These longer times should not be counted when determining how much delay is caused to legal trucks by the weighing operation.

#### [Tests]

Each branch and parking lot link performs a test on each vehicle as it enters the link. The test is a Boolean combination of vehicle attributes. If the value of the test is true, the vehicle leaves the branch link by the alternate link (the second link named in the link file). If the value of the test is false, the vehicle leaves the branch by the main link (the first link named in the link file). More than one branch may perform the same test. If an attribute number is specified in the second part of the test, that attribute is set to true for all vehicles that pass the test.

**2 "trucks right"                    A { 2 } { }**

All trucks (not including pickup trucks) take the alternate branch to the right. This test is used twice: first to move any trucks still in the left lane when the station is at hand (link 4) to the right lane (link 15), and then to move all trucks from the right lane onto the exit ramp (link 21).

**3 "tag weighed"                    A { 2 ) { 6 }**

This test simply tags all trucks that go past the static scales (link 24) as being weighed (i.e. attribute 6 is set to true). This tag is used for reporting purposes only.

**4 "to parking lot"                A { ( 3 or 4 or 5 ) and ( not 8 ) } { }**

All trucks that are overweight (attribute 3) or unsafe (attribute 4) or have credentials problems (attribute 5) and are not coming around for the second time (not attribute 8) take the alternate branch from the scales toward the parking lot. All other trucks take the primary branch back to the highway. This test is applied by link 24 (the scale link).

**5 "safety check"                    A { not 7 } { 9 }**

This test is performed in the parking lot (link 32). All vehicles that are not fixable (not attribute 7) are tagged with attribute 9 (out of service). Those trucks will not leave the parking lot. Otherwise, after waiting the appropriate length of time, they return to the highway.

**6 "fix some"                        A { 7 } { 8 }**

Trucks leaving the parking lot go through a branch (link 33) with this test. Since all vehicles leaving the parking lot are fixable, no trucks fail this test. In fact, both exit links are the same. The only purpose of this test is to set attribute 8 (2<sup>nd</sup> pass okay) to true for those trucks, so they do not have to enter the parking lot again. Because of the order the attributes are defined, trucks with attribute 8 true are displayed with blue trailers, regardless of their previous trailer color.

**7 "tag misses"                      A { not 1 } { 10 }**

When trucks bypass the station on link 16 because it is closed, this test sets attribute 10 to true, so the number of bypassed trucks can be counted.

**8 "tag ovwt misses"                A { 3 } { 11 }**

When an overweight truck (attribute 3) bypasses the station on link 16 because it is closed and goes on to link 17, this test sets its attribute 11 to true, so the number of overweight bypassed trucks can be counted.

**9 "legal in station"                A { not 3 and ( not 4 ) and ( not 5 ) } { 12 }**

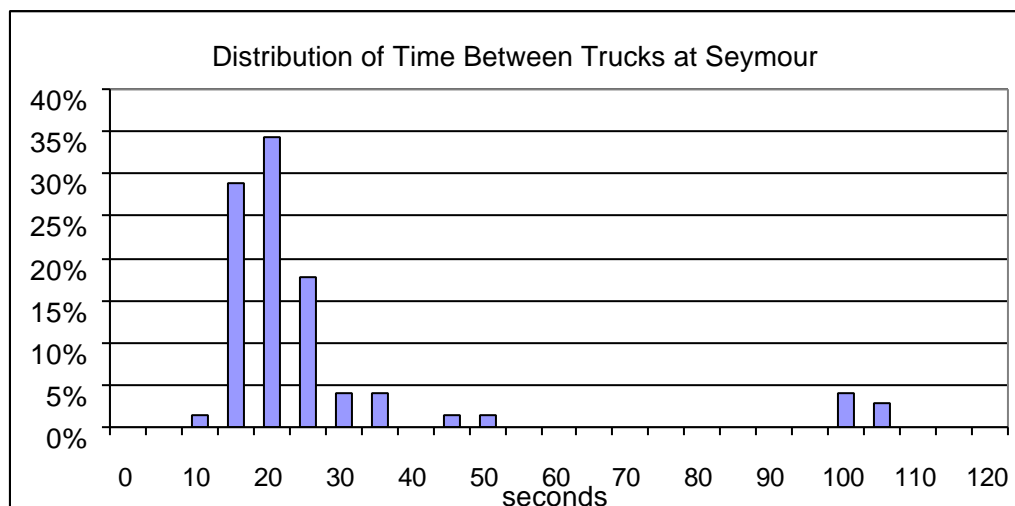
When a legal weight truck with no safety or credential problems (attributes 3, 4, and 5 are all false), approaches the scale on link 23, this test sets attribute 12 to true. The purpose of this attribute is to be able to compute the average transit time for these vehicles. The average time for trucks that have problems is much longer, and should be excluded from the desired delay to legal trucks.

#### [ServiceTimes]

Service times are specified for scales and branches as probability distributions. Different distributions may be specified for different Boolean combinations of vehicle classes. The types of possible distributions are Normal, Uniform, Erlang, or Constant.

#	name	expression	random type	parms
1	"weighing time"	{ 8 } Constant 0 { } Erlang 7		

The service time distribution was calculated from data recorded by Richard Glassco while observing the Seymour facility in March 1998. He recorded 75 observations, timing from when one truck left the scales to when the next truck left the scales. The distribution of this data is shown in figure 3-5. The plot suggests that the distribution of service times is consistent with an Erlang distribution (see figure 2-6). The average value is 25 seconds. The average time in Westa between the time one truck starts to leave the scales and the time the next truck pulls and stops on the scales is 18 seconds. Mitretek therefore assumed an Erlang weighing time distribution with an average of 7 seconds and an average of 18 seconds for the next truck to pull into place. However, if the truck has already been detained and is coming around the second time (attribute 8 is true), then it is not weighed again, so its service time is zero.



**Figure 3-5. Distribution of Time between Trucks on Scale at Seymour**

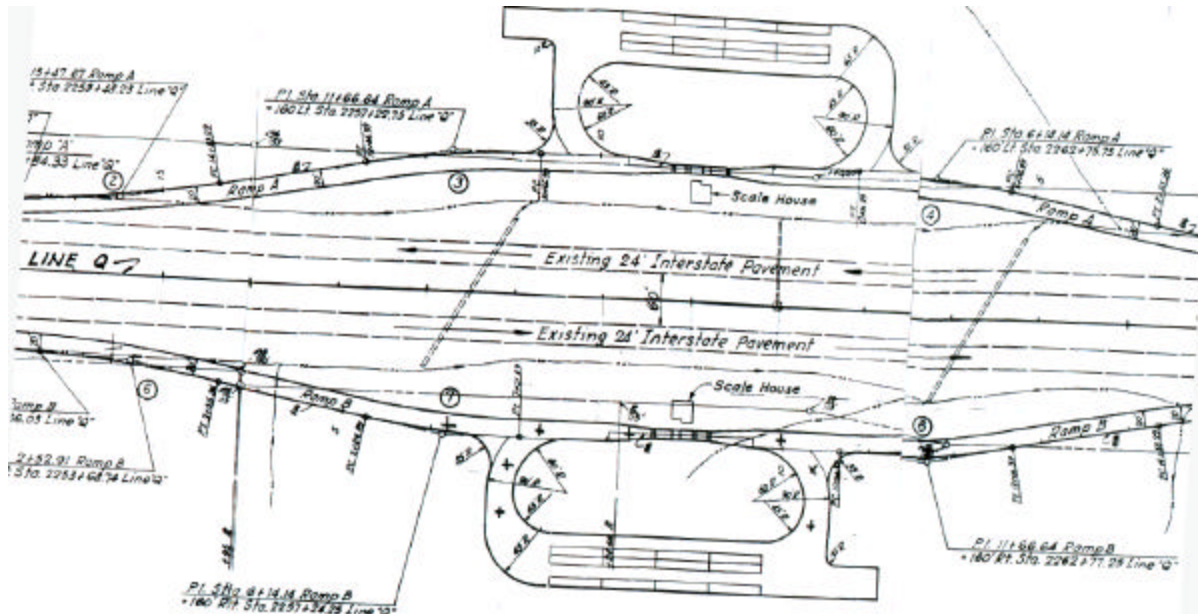
2	"inspection time"	{ 3 } Erlang 600 { 4 } Erlang 1500 { 5 } Erlang 300
---	-------------------	---

Mitretek did not receive data on time spent being inspected from Indiana, so data from South Dakota were used instead. SDDOT supplied recorded data grouped by safety, credential, and overweight checks on the elapsed time between when each truck entered the parking lot to when it left. These times are of secondary importance to the results obtained for the Seymour station because overflow is caused by queuing for the static scale, not by trucks in the parking lot.

#### [LinkInfo]

This section specifies information for each link in the simulation. The first column is the link number. The second column gives the type of link. The third and fourth columns specify the first and second

links following the given link. Two exit links are specified only if the link is a branch or scale; otherwise there is a dash (-). The fifth column specifies the free speed limit in miles per hour. The sixth and seventh columns specify the x and y coordinates (in feet) of the start of the link and the eighth and ninth columns specify the x and y coordinates of the end of link. Mitretek determined the link coordinates from the scale drawing of the Seymour facility provided by INDOT, shown in figure 3-6.



**Figure 3-6. Scale Drawing of Seymour Station from INDOT**

The remaining fields are optional, depend on the type of link, and may be specified in any order. A “T” precedes the test number for a branch link. An “ST” precedes the service time number for a branch or scale link. A “Y” indicates that traffic on that link must yield when merging with traffic from another link. A “CC” precedes the coordinates of the center of curvature for a curved link. A “PS” precedes the number of parking spaces for a parking lot, and an “OC” precedes the x and y coordinates of the opposite corner of a parking lot (the corner directly opposite the corner where trucks enter the lot.). An “A” indicates the proportion of arrivals to appear on each origin link. An “LL” indicates the link number of the left-hand lane for lane-changing purposes, while an “RL” indicates the link number of the right-hand lane.

Notes on individual links follow the listing. Figure 3-7 provides an overview of the station as modeled in Westa, showing link numbers. Figure 3-8 presents a close-up of the central weighing and inspection area.



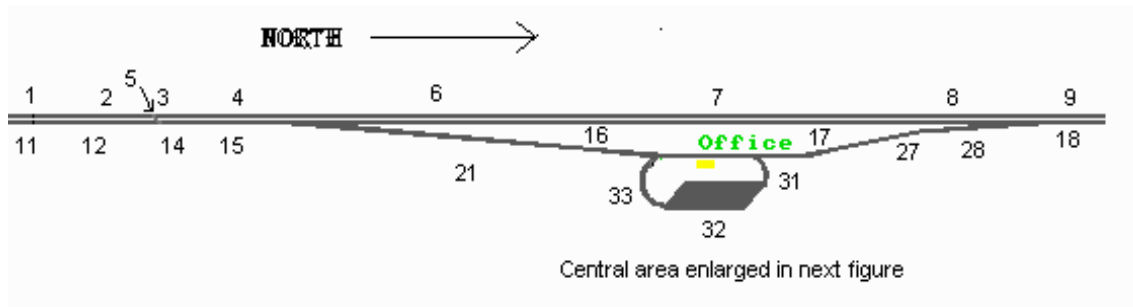


Figure 3-7. Overview of Seymour Station on Northbound I-65

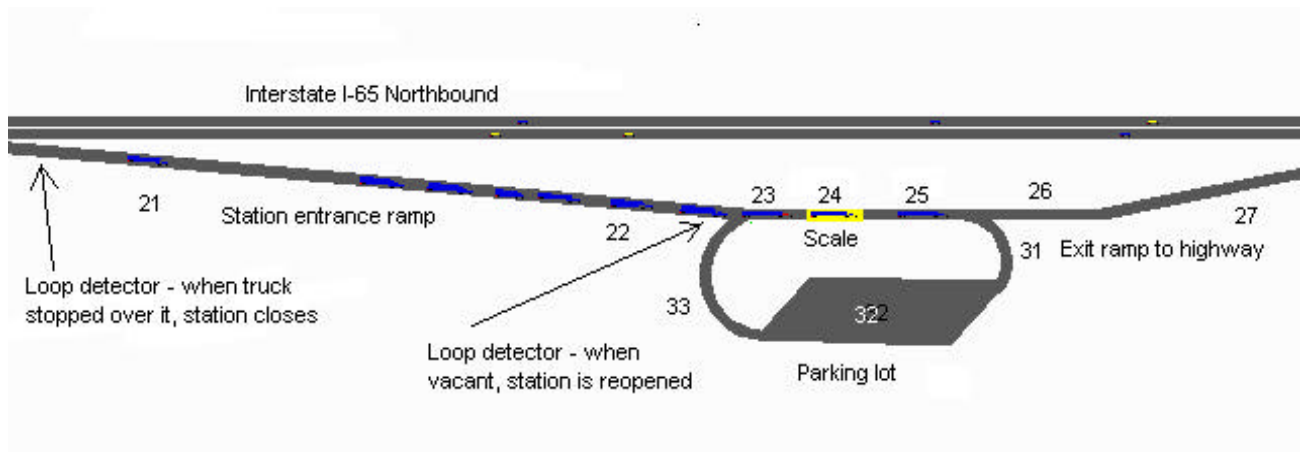


Figure 3-8. Detail of Central Area of Seymour Station

#	type	ahead	spd	start	x&y	end	x&y	key	terms
#	----	---	---	----	----	----	----	-----	-----
1	Orig	2	-	55	0	365	200	365	A .37
2	Trans	3	-	55	200	365	1700	365	RL 12
3	Branch	4	5	55	1700	365	2000	365	T 2
4	Trans	6	-	55	2000	365	2450	365	
5	Trans	14	-	55	2000	365	2100	350	Y
6	Trans	7	-	55	2450	365	3000	365	
7	Trans	8	-	55	3000	365	4000	365	RL 16
8	Trans	9	-	55	4000	365	5300	365	
9	Dest	-	-	55	5300	365	5500	365	
11	Orig	12	-	55	0	350	200	350	A .63
12	Trans	14	-	55	200	350	2100	350	LL 2
14	Trans	15	-	55	2100	350	2450	350	
15	Branch	16	21	55	2450	350	3000	350	T 2 LL 6
16	Branch	17	17	55	3000	350	4000	350	T 7 LL 7
17	Branch	18	18	55	4000	350	5300	350	T 8 LL 8
18	Dest	-	-	55	5300	350	5500	350	
21	Trans	22	-	35	3000	350	3900	270	C .50 O .0 SC Q
22	Trans	23	-	25	3900	270	4130	250	Q AS 33

23 Branch	24	24	20	4130	250	4275	250	Q	T	9
24 Branch	25	31	5	4275	250	4410	250	ST	1	T 4
25 Branch	26	26	25	4410	250	4580	250	T	3	
26 Trans	27	-	25	4580	250	4680	270			
27 Trans	28	-	35	4680	270	4930	320			
28 Trans	18	-	55	4930	320	5300	350	Y		
31 Trans	32	-	10	4410	250	4450	160	CC	4403	192
32 Park	33	33	5	4450	160	4150	100	ST	2	T 5 OC 4388 94 PS 16
33 Branch	23	23	10	4150	100	4130	250	T	6	CC 4157 176
38 Bldg	-	-	-	4250	210	4302	236	"Office"		

Links 1 through 9 are the left lane of Northbound I-65. Link 1 is the origin link, delivering 37 percent of the vehicles. Link 2 is a long transit link. Any trucks on link 2 may shift right to link 12 if there is sufficient room. Cars may switch lanes at will, given a sufficient gap, but trucks may only shift to the right lane from the left lane.

All trucks that haven't shifted to the right lane by the end of link 2 are sent by branch link 3 to transit link 5, which merges with link 12 into link 14. Traffic on link 5 yields to traffic on link 12. Cars, buses, and pickup trucks on link 3 continue on link 4 to links 6, 7, 8, and 9, bypassing the weigh station. Any of these vehicles on link 7 may change lanes to the right lane onto link 16. Vehicles completing destination link 9 exit the simulation.

Links 11 through 18 are the right lane of northbound I-65. Link 11 is the origin link, delivering 63 percent of the vehicles. Cars, buses, and pickup trucks on links 12, 15, 16, and 17 may change lanes to the left onto links 2, 6, 7, and 8 respectively if there is enough space. Link 15 is the branch link in the right lane. At the end of this branch, all trucks must exit the highway into the station on the ramp link 21. Cars and pickup trucks continue on link 16. Link 16 is a branch only so that test 7 can be applied, setting the bypass attribute for any trucks that bypass the station. Both exit links for link 16 are the same. Similarly, link 17 is a branch only so that test 8 can be applied, setting the bypass attribute for any overweight trucks that bypass the station. Vehicles completing destination link 18 exit the simulation.

Link 21 is the ramp into the station. The parameters for link 21 specify that when it is more than 50% full, it closes. The percentage full is computed by dividing the length of trucks on the link to the link length. Mitretek has found that this procedure detects when the ramp is full of trucks better than judging whether a truck over a loop detector is stopped at the end of the queue or not. When link 21 is closed, the station is closed, and all trucks on link 15 bypass the station on link 16. When the length of trucks on link 21 is reduced to 0% of the ramp length, the ramp reopens, and trucks again enter that link.

Link 22 is the continuation of the ramp into the station. Exit from the link is controlled by an actuated signal. Whenever there is a truck on link 33 coming out of the parking lot, the light turns red and trucks may not exit link 22. Although there is no such signal at the Seymour station, this is Westa's way of modeling the fact that trucks exiting the parking lot have the right of way. On link 23, the "legal in station" attribute is set to true for underweight trucks with no credential or safety problems.

Link 24 is the scale where test 4 is applied (is the truck overweight or is there a reason for a safety or credential check?) If any of these are true, and the truck has not been inspected before, the truck

must take the right branch (link 31) to the parking lot. If no further check is required, the truck may take the left branch (link 25) toward the station exit. Service time 1 defines the distribution of times to weigh a truck and make the safety/credential determination.

Link 25 leads to links 26, 27, and 28, the reentry ramp onto the highway. On link 25, each truck's "weighed" attribute is set to true. Trucks on link 28 must yield to highway track on link 17, as both links merge onto link 18.

Link 31 leads to link 33, the parking lot. In the parking lot, test 5 (safety inspection) is applied. Service time 2 defines the distribution of times to perform a safety, credential, or weight distribution inspection and to fix the problem. If the truck is fixable, after waiting the appropriate time, it exits the lot on link 33. On link 33, the truck's attribute 8 (2<sup>nd</sup> pass okay) is set to true so the truck is not pulled over a second time. At the Seymour station, trucks park parallel to the side of the lot. Westa cannot represent parallel parking; rather all trucks park at an angle. Mitretek was not concerned about the difference in the direction of truck parking since time spent in the parking lot was not a significant factor in the measures of effectiveness.

Link 38 is not a link at all, but a stationary building, the office. Links defined as buildings are simply shown on the display with a label.

#### [GraphInfo]

The following lines define the statistics boxes in the lower left corner of the screen. The first five statistics display the current cumulative count of vehicles with certain attributes. A vehicle does not get counted in these statistics until it leaves the simulation, either by exiting a destination link or by being placed out of service in the parking lot. The sixth statistic displays the cumulative average transit time for all underweight trucks with no credential or safety problems that finish the simulation. The last statistic gives the total number of trucks in links defined with a "Q" (i.e. links 21, 22, and 23).

```
Stat  "Total number of trucks" Count 2
Stat  "Overweight trucks"      Count 3
Stat  "Trucks weighed"         Count 6
Stat  "Trucks bypassed"        Count 10
Stat  "Overweights bypassed"   Count 11
Stat  "Average time"           Time 9
Stat  "Queue length"           QueueLen
```

The following lines define five "views". These are preset coordinates that can be invoked by pressing a single number key during the simulation.

```
View 1  -44  1265  -159  823
View 2   872  2181  -159  823
View 3  1658  2967  -159  823
View 4  3857  4695  -108  521
View 5  4544  5214   -45  458
```

[End]

Note: other data collected by Mitretek at the Seymour station, including number of trucks in queue, frequency of queue overflow, and number of trucks in the parking lot were not used as input. Instead they were used for validating the output of the model.

### 3.2 Longer Ramp Scenarios

At the request of the Indiana State Police, Mitretek ran two scenarios where the length of the weigh station entrance ramp was lengthened. In the first alternate scenario, the length was increased by 1000 feet. In the second alternate scenario, the length was increased by 2000 feet. Mitretek was not concerned about whether there was room to extend the ramps at the actual Seymour facility. A bridge reconstruction project planned for the next few years might be coordinated with a ramp extension project.

The only difference in the Westa data files defining these two alternate scenarios is that the coordinates of the end of the station entrance ramp and the coordinates of all links beyond that point are increased by 1000 or by 2000. Mitretek identified these two scenarios as “L1K” and “L2K.”

### 3.3 Transponder Scenarios

Mitretek ran six alternate scenarios with varying proportions of trucks with in-cab transponders. The scenarios labeled T05, T10, T20, T30, T40, and T50 featured 5%, 10%, 20%, 30%, 40%, and 50% transponder equipage, respectively. In each scenario, only trucks of legal weight with no credential or safety issues were considered for transponders. For example, in the 20% transponder scenario, each time a truck that is not a pickup is generated, and the truck does not have attribute 3 (overweight), attribute 4 (safety problem) or attribute 5 (credential problem) set to true, a random number between 0 and 100 is drawn. If the number is less than 20, the truck is considered to have a transponder and attribute 12 is set to true.

There are a few differences between the Westa data files defining the transponder scenarios and the base scenario. First, the transponder attribute is defined, as described above. The cabs of trucks with transponders are drawn to the screen in green. The color green was chosen to suggest a green light and the cab was indicated because that is the location of the transponder.

```
[Attributes]
# name          cab color  trailer color  %   expr      %   expr
# ----          -
12 "transponder" lightgreen    default      20 { 2 and ( not 3 ) and
                                ( not 4 ) and ( not 5 ) }
```

Second, the “legal in station attribute was changed to attribute 13, and the check for it was changed accordingly.

```
[Attributes]
# name          cab color  trailer color  %   expr      %   expr
# ----          -
13 "legal in station" default      default      0 { }
```

```
[Tests]
# name          ret expression          assignments
# ----          -
```

```
9 "legal in station"      A { not 3 and ( not 4 ) and ( not 5 ) } { 13 }
```

Third, a test was defined to look for trucks with transponders.

```
[Tests]
# name          ret expression      Assignments
# ----
1 "transponder check"  A { 2 and ( not 12 ) } { }
```

Finally, the branch link just before the station entrance ramp uses the new test 1 rather than test 2, which requires all trucks to exit. Thus only trucks without transponders are required to exit the highway.

```
15 Branch 16 21 55 2450 350 3000 350 T 1 LL 5
```

### 3.4 Weigh-in-Motion Scenario

At the request of the Indiana State Police, Mitretek modeled a scenario where a low-speed WIM scale would be installed on the station entrance ramp, and a bypass lane would be built between the current scale facility and the highway. A variable message sign following the WIM scale would direct trucks weighed over a certain threshold to proceed to the static scale, and would direct trucks weighed under that threshold to use the bypass lane. Recognizing that a measurement from a WIM scale is not as accurate as a measurement from a static scale, the threshold for sending a truck to the static scale is typically set less than the legal weight limit. For this scenario, Mitretek set the threshold at 65,000 pounds, and assumed the WIM scale had a 5% error rate. This means that the weight of a truck passing over the scale is measured as its simulated weight plus or minus a random number drawn from a normal distribution with mean zero and standard deviation 5% of the simulated weight.

The WIM scenario was modeled with the following changes in the input file. Link 21 was changed from a standard transit link to a scale link with threshold 65,000 and error .05. Link 29 is the bypass link, which merges with link 26 onto link 27. The speed limit on the bypass link is 25 miles per hour. Figure 3-7 shows the bypass link.

```
21 Scale 29 22 35 3000 350 3900 270 Q W 65000 E .05 SC C 0.50 O 0.0
29 Branch 27 27 25 3900 270 4680 270 T 9
```

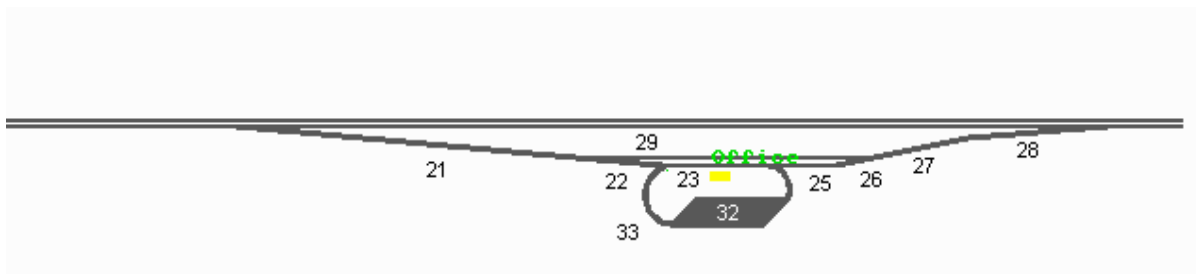


Figure 3-9. Detail of Proposed Bypass Ramp in Station

### 3.5 Decreased Traffic Scenarios

Thus far ten scenarios have been described: the base scenario, two longer ramp scenarios, six transponder scenarios, and a WIM scale scenario. The results showed heavy congestion and frequent queue overflows. On the chance that data collected at the Edinburgh site during ten days in April 1998 was too high to represent typical peak hour arrival rates at the Seymour station, Mitretek ran the same ten scenarios with 20% less traffic to simulate a less demanding load. The only change to the input files was an increase in vehicle interarrival time, which decreased the hourly number of arrivals by 20%. The arrival rate for each class of vehicles increased by the same amount.

```
avgCreatTime:    3.2                                # peak hour 3-5 p.m.
```

### 3.6 Alternate WIM Scenarios with Increased Traffic

Mitretek observed significant congestion for all the alternate scenarios except the WIM scenario. In order to determine whether the WIM scale could handle increases in truck traffic beyond the base case scenario, Mitretek ran the WIM scenario again with the traffic load increased by 20% and by 40%. A fact sheet from the trucking industry's Team 2000 predicts that "In the year 2006 ... the total number of miles driven [by trucks] will have grown by 28% and the total volume of ton-miles will have grown by 32%." The only change to the WIM input file was the decrease in vehicle interarrival time, which increased the hourly number of arrivals by 20% or by 40%. The arrival rate for each class of vehicles increased proportionately by the same amount.

```
avgCreatTime:    2.13                                # peak hour 3-5 p.m.
avgCreatTime:    1.83                                # peak hour 3-5 p.m.
```

Next Mitretek ran the same three scenarios (base arrival rate plus two increased arrival rates) for the scenario where the threshold for bypassing trucks weighed by the WIM scale was set at 75,000 pounds rather than 65,000 pounds. Setting a higher threshold increases the possibility that an overweight truck is weighed by the WIM scale as under the threshold. Overweight trucks that bypass the static scale for this reason are counted as if they had bypassed the station because of queue overflow.

```
21 Scale  29 22  35   3000  350 3900  270 Q W 75000 E 0.05 SC C .50 O .0
```

## Section 4

# Representation of the McCook Weigh Station Scenarios

This section describes the McCook weigh station base case scenario and alternate scenarios and documents the input files defining the scenarios.

### 4.1 Description of Scenarios

The base case scenario was constructed using data defining current station design and operation. The results of the base case scenario can be compared to current conditions at the station. Section 4.2 documents the input file for the base case.

The first alternate scenario represents the proposed replacement facility and operating policy. The station layout would be similar to the existing layout, except for the addition of a low-speed WIM scale on the station entrance ramp, and a bypass lane between the scale facility and the highway. A branch from the bypass lane to the parking lot would enable the station operator to direct trucks with possible safety or credential problems to the inspection lot. The only trucks sent to the static scale would be trucks that exceed the maximum weight on any single axle, plus a randomly chosen 10 percent of trucks over 80,000 pounds gross weight. The axle weight and gross weight measurements would be performed by the WIM scale on the entrance ramp. This scenario represents a lower bound on the number of trucks weighed. The input file for this scenario is documented in section 4.3.

The second alternate scenario is an alternate operating policy at the proposed station. First, the threshold for gross weight was set to 70,000 pounds rather than 80,000 pounds. The lower threshold allows for error in the WIM scale, reducing the chance that an overweight truck would be measured as under the threshold. It is acknowledged that the gross weight threshold is more simplistic than using thresholds specific to vehicles' axle configurations. Second, all trucks measured by the WIM scale as over 70,000 pounds would be sent to the static scales, rather than a random sample. This scenario is an upper bound on the number of trucks sent to the static scales from a WIM scale. The input file for this scenario is documented in section 4.4.

At the request of SDDOT, Mitretek ran each of the three scenarios again with the traffic load increased by 20% and by 30%. A fact sheet from the trucking industry's Team 2000 predicts that "In the year 2006 ... the total number of miles driven [by trucks] will have grown by 28% and the total volume of ton-miles will have grown by 32%." The arrival rate for each class of vehicles increased proportionately by the same amount. Section 4.5 describes how these scenarios were defined.

In all, nine scenarios were modeled. Table 4-1 summarizes the nine scenarios.

Arrival Rate	Base Case Scenario	First Alternate Scenario	Second Alternate Scenario
Base	x	x	x
120%	x	x	x
130%	x	x	x

**Table 4-1. Scenarios Modeled**

## 4.2 Base Case Scenario

For each value or set of values, the source of the information is given. The lines of the input file are shown in bold Courier font, and the commentary follows in Times New Roman font. Any characters following the pound sign (#) in the input file are treated as comments. The complete input file is presented in Appendix B.

### **McCook 100% Base case scenario**

The scenario name is displayed at the top of the screen and included in the output files. The traffic level simulated is 100% of the current traffic load.

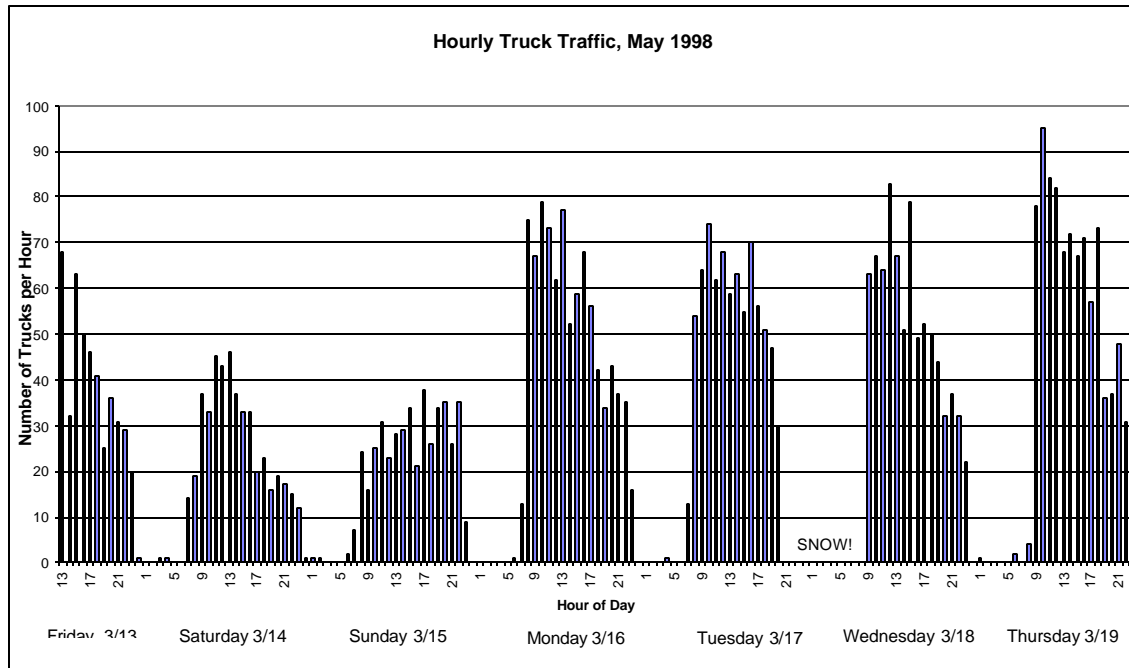
**runLength: 120 # run for two hours**

The scenario runs for two hours, representing the fairly steady truck traffic during the peak period in the late morning. Figures 4-1 and 4-2 depict truck traffic counts taken by SDDOT during March 1998 and June 1998. Both show peak periods for truck traffic in the late morning and early afternoon on weekdays. Truck traffic on weekends is significantly less. Figure 4-3 shows the hourly car and truck traffic averaged across the weekdays in March. Clearly the peak hours for cars correspond to morning and evening rush hours, but the peak hour for trucks is between 10 and 11 a.m.

**randomSeed\_truck: 101**

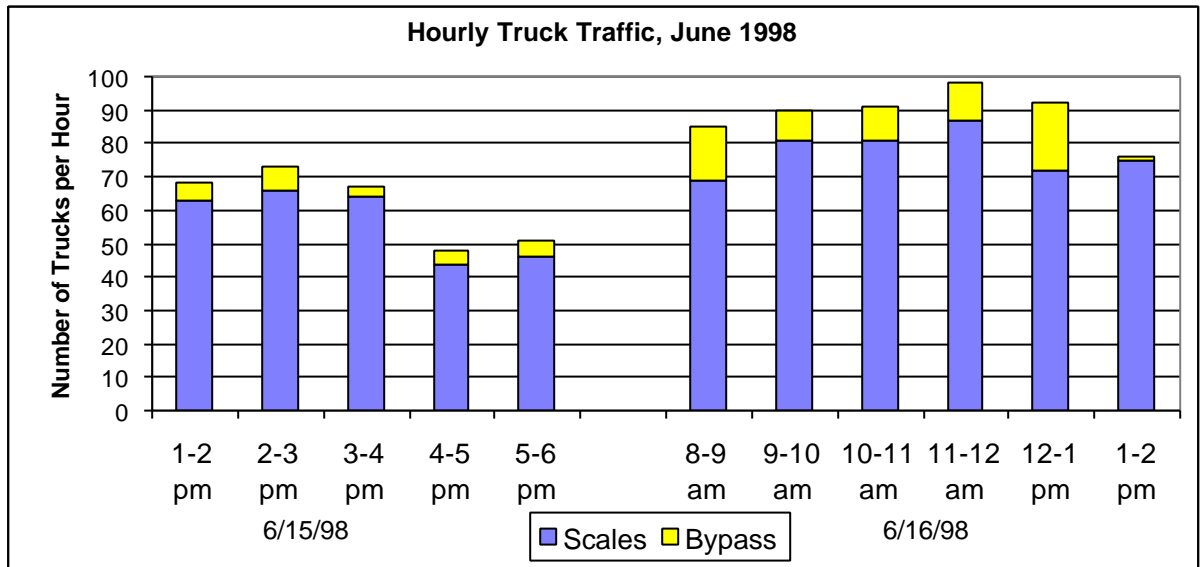
**randomSeed\_link: 11**

These random seeds initialize the random number generators for vehicle generation and weighing/inspection times. The numbers here were used for the first iteration. Mitretek ran each scenario ten times with a different pair of random seeds for each iteration, and averaged the results together for the results presented in Section 7.

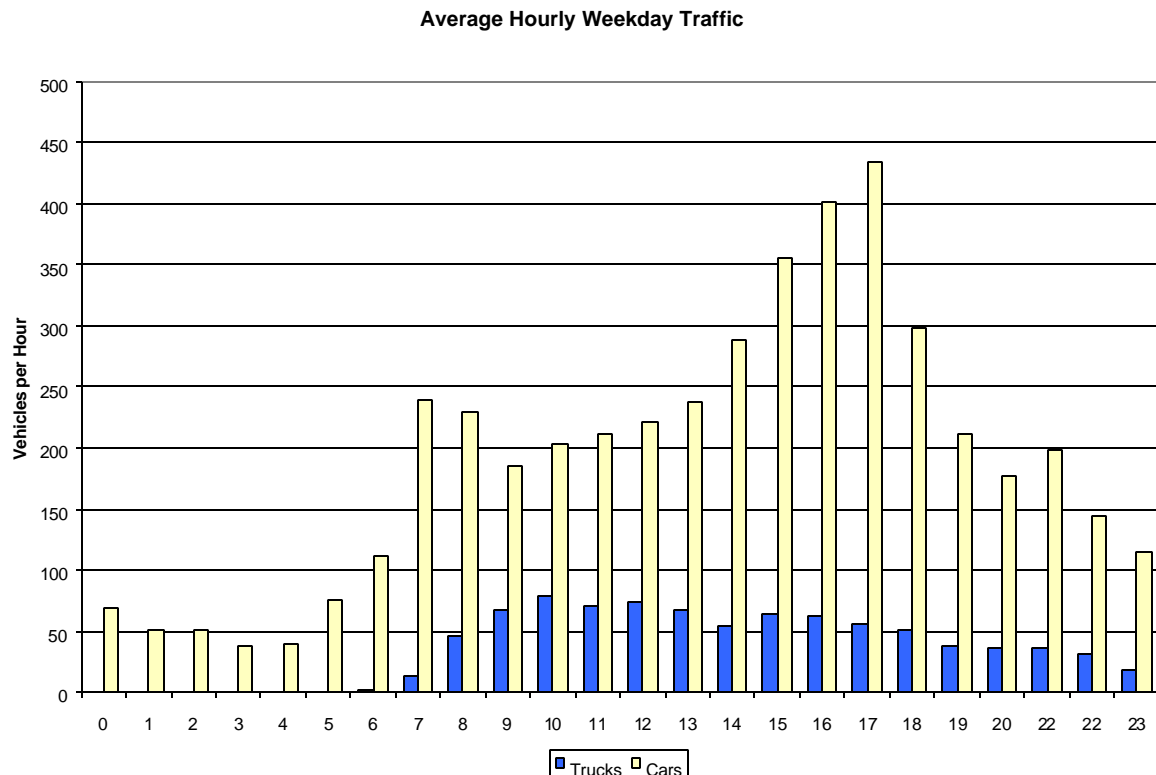




**Figure 4-1. Hourly Count of Trucks at McCook Station – March 1998**



**Figure 4-2. Hourly Count of Trucks at McCook Station – June 1998**



**Figure 4-3. Truck and Car Traffic Averaged by Hour across Weekdays**

**avgCreatTime:** 10 # (sec.)

A vehicle is generated every 10 seconds on the average. The vehicle has a 24.4% chance of being a truck (see the truck info section), so a truck is generated every 41 seconds on the average, for an arrival rate of 88 trucks per hour. An arrival rate of 88 trucks per hour is roughly equal to the hourly arrival rate in the morning of March 19, the busiest of the days measured in March 1998 (see figure 4-1). It is also roughly equal to the hourly arrival rate in the morning of June 16, 1998, when additional measurements were recorded by SDDOT (see figure 4-2).

Section 4.5 describes the set of scenarios with higher levels of traffic demand.

**maxWt:** 80000 # <- maxWt for static scales

The maximum legal gross weight for trucks without a special permit is set at 80,000 pounds per South Dakota regulations. Trucks weighing more than 80,000 pounds are considered overweight.

**TimeStep .1**

The size of the time step was reduced from one second to 0.1 second to enable detailed modeling of vehicle response to potentially hazardous situations. Driver perception-reaction times vary from 0.8 to 2.4 seconds, and vehicles have a corresponding lag in their behavior. Time steps as small as 0.1 seconds are required to model the effects of these different perception-reaction times.

**[TruckInfo]**

The following groupings define the distribution of length, weight, and acceleration/ deceleration characteristics for vehicles in each FHWA class. When values for any of these variables are not specified for a class, Westa uses values for the preceding class.

**Class 2 Cars**

**maxAccRange:** 2.8 6.3 .009 # (mi/hr/sec)

The maximum acceleration rate for each car is chosen from a uniform distribution between 2.8 and 6.3 mph per second. These values reflect the range of maximum acceleration capabilities for passenger cars reported in the Road Test Digest of Car and Driver magazine. Those acceleration figures are divided by two since the maximum acceleration used on a freeway is less than the maximum value on a test track. The value of 0.009 indicates that the maximum acceleration rate declines at .009 times the current speed (the faster a car is going, the smaller is its maximum acceleration).

**maxDecRange:** 17.3 20.7 .30 # (mi/hr/sec)

The maximum deceleration rate for each car is chosen from a uniform distribution between 17.3 to 20.7 mph per second. These values are the weighted averages plus and minus two standard deviations for maximum deceleration rates for passenger cars published in Consumer Reports magazine. The value of 0.3 indicates that the normal (comfortable) rate of deceleration is 0.3 times the maximum rate.

**weightRange:** 0 6000 # (lbs)

**weightDistrib:** 0.0 0.0 4.1 9.9 31.4 27.3 14.9 6.6 4.1 1.7 # (%)

The minimum and maximum weights serve as end points for the weight distribution. The weight range is divided into ten bins of equal size between the minimum and maximum value, and the percentages give the percent of cars in each bin. In this case, the bin size is 600 pounds. The values of weight

distribution for cars reflect the weight range of new cars reported in Consumer Reports magazine. The weight of cars is irrelevant to the McCook model in any case.

```
lengthRange: 10 20 # (ft)
lengthDistrib: 0.0 0.0 1.7 7.4 19.0 28.9 27.3 10.7 5.0 0.0 # %
```

The minimum and maximum lengths serve as end points for the weight distribution. The length range is divided into ten bins of equal size between the minimum and maximum value, and the percentages give the percent of cars in each bin. In this case, the bin size is 1 foot. The values of length distribution for cars reflect the length range of new cars reported in the March 1998 Consumer Reports magazine.

```
Class 3 2-axle 4-tire (Pickup trucks)
maxDecRange: 16.8 18.6 .30 # (mi/hr/sec)
```

The maximum deceleration rate for light trucks ranges from 16.8 to 18.6 mph per second. These values are the weighted averages plus and minus two standard deviations for maximum deceleration rates for light trucks published in Consumer Reports magazine. The value of 0.3 indicates that the normal (comfortable) rate of deceleration is 0.3 times the maximum rate.

```
lengthDistrib: 0.0 0.0 96.2 0.0 0.2 1.5 1.9 0.3 0.0
```

The length distribution for this class and for all truck classes was supplied by SDDOT. Since the maximum and minimum lengths are not specified, the values for the previous class are used. Similarly, since the acceleration and weight characteristics of class 3 trucks are not specified, the values for cars are used. The length and weight of pickup trucks are irrelevant to the model in any case since they are not inspected.

```
Class 4 Buses
maxDecRange: 16.8 18.6 .30
lengthRange: 30 40
lengthDistrib: 0.0 0.0 96.2 0.0 0.2 1.5 1.9 0.3 0.0
```

The same deceleration characteristics were used for buses as for small trucks. The distribution of bus lengths came from SDDOT. Bus characteristics are not significant to the McCook model since they are not inspected.

```
Class 5 2-axle 6-tire single units
```

The performance characteristics of class 5 trucks were assumed to be the same as for light trucks so they are not specified.

```
weightRange: 0 100000
weightDistrib: 0.7 23.1 28.6 20.4 14.3 12.2 0.0 0.0 0.7 0.0 # (%)
```

The weight distribution supplied by SDDOT for “straight trucks” was used for class 5 trucks. A chart of weight distribution for all truck classes supplied by SDDOT is presented in table 4-2.

```
lengthRange: 0 50 # (ft)
lengthDistrib: 0.0 2.4 64.1 23.6 9.9 0.0 0.0 0.0 0.0 0.0
```

The length distribution for this class and for all truck classes was supplied by SDDOT.

```
Class 6 3-axle single units
maxAccRange: 1.3 2.6 .009 # (mi/hr/sec)
```

The maximum acceleration rate for each large truck (class 6 and above) is chosen from a uniform distribution between 1.3 and 2.6 mph per second. These values range around the value of .1g (2.2

mph) considered good acceleration for a loaded truck. The value of 0.009 indicates that the maximum acceleration rate declines at .009 times the current speed (the faster a truck is going, the smaller is its maximum acceleration).

Bin	Straight Class 5	3-axle Class 6	4-axle Class 7	Trailer Class 8	5-axle Class 9	6-axle Class 10	Double Class 11	Double Class 12	7+-axle Class 13
0-10K	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10-20K	0.231	0.000	0.000	0.206	0.000	0.000	0.000	0.000	0.000
20-30K	0.286	0.000	0.096	0.147	0.001	0.000	0.000	0.000	0.000
30-40K	0.204	0.846	0.386	0.088	0.039	0.000	0.019	0.019	0.000
40-50K	0.143	0.154	0.434	0.029	0.133	0.019	0.101	0.101	0.000
50-60K	0.122	0.000	0.084	0.029	0.157	0.113	0.335	0.335	0.000
60-70K	0.000	0.000	0.000	0.176	0.157	0.170	0.424	0.424	0.000
70-80K	0.000	0.000	0.000	0.324	0.485	0.245	0.082	0.082	0.000
80-90K	0.007	0.000	0.000	0.000	0.027	0.245	0.019	0.019	0.000
90-100K	0.000	0.000	0.000	0.000	0.000	0.132	0.013	0.013	0.000
100-110K	0.000	0.000	0.000	0.000	0.000	0.075	0.000	0.000	0.000
110-120K	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.006	0.111
120-130K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.222
130-140K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.111
140-150K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.111
150-160K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.222
160-170K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.222

**Table 4-2. Distribution of Truck Weights by FHWA Class**

**maxDecRange:**        12.8    16.0            .30                    # (mi/hr/sec)

The maximum deceleration rate for trucks ranges from 12.8 to 16.0 mph per second. The upper value was supplied by data in the American Trucking Association library. The lower value was based on the assumption that some trucks will have less than optimal brakes. The value of 0.3 indicates that the normal (comfortable) rate of deceleration is 0.3 times the maximum rate.

**weightRange:**        0            100000                    # (lbs)

**weightDistrib:**    0.0    0.0    0.0    84.6    15.4    0.0    0.0    0.0    0.0    0.0    # (%)

The weight distribution supplied by SDDOT for “3-axle trucks” was used for class 6 trucks.

**lengthRange:**        0            50

**lengthDistrib:**    0.0    0.0    0.8    18.7    72.3    8.2    0.0    0.0    0.0    0.0    # %

The length distribution for this class and for all truck classes was supplied by SDDOT.

**Class 7    4 or more axles, single unit**

**weightRange:**        0            100000

**weightDistrib:**    0.0    0.0    9.6    38.6    43.4    8.4    0.0    0.0    0.0    0.0    # (%)

The weight distribution supplied by SDDOT for “4-axle trucks” was used for class 7 trucks.

**lengthRange:**        0            50

**lengthDistrib:**    0.0    0.0    0.0    11.5    50.0    34.6    3.8    0.0    0.0    0.0    # %

The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 8 4 or fewer axles, single trailer

weightRange: 0 100000

weightDistrib: 0.0 20.6 14.7 8.8 2.9 2.9 17.6 32.4 0.0 0.0 # (%)

The weight distribution supplied by SDDOT for "Trailer trucks" was used for class 8 trucks.

lengthRange: 20 70 # (ft)

lengthDistrib: 0.0 6.8 22.4 35.1 16.4 7.4 6.5 4.2 1.1 0.0 # %

The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 9 5-axle, single trailer

weightRange: 0 100000

weightDistrib: 0.0 0.0 0.1 3.9 13.3 15.7 15.7 48.5 2.7 0.1 # (%)

The weight distribution supplied by SDDOT for "5-axle trucks" was used for class 9 trucks.

lengthRange: 35 85

lengthDistrib: 0.2 0.6 2.1 10.0 37.1 46.0 3.9 0.2 0.0 0.0 # %

The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 10 6 or more axles, single trailer

weightRange: 10000 110000

weightDistrib: 0.0 0.0 0.0 1.9 11.3 17.0 24.5 24.5 13.2 7.6 # (%)

The weight distribution supplied by SDDOT for "6-axle trucks" was used for class 10 trucks. Note that the weight range is now 10,000 pounds to 110,000 pounds. The range was changed to reflect the chance of class 10 trucks over 100,000 pounds.

lengthDistrib: 0.0 0.0 0.9 8.8 31.0 27.9 27.4 3.5 0.4 0.0 # %

The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 11 1.1 % 5 or fewer axles, multi-trailer

weightRange: 20000 120000

weightDistrib: 0.0 1.9 10.1 33.5 42.4 8.2 1.9 1.3 0.0 0.6 # (%)

The weight distribution supplied by SDDOT for "Double" trucks was used for class 11 trucks. The range is from 20,000 pounds to 120,000 pounds.

lengthDistrib: 0.0 0.0 0.9 8.8 31.0 27.9 27.4 3.5 0.4 0.0 # %

The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 12 6 axles, multi-trailer

weightRange: 20000 120000

weightDistrib: 0.0 1.9 10.1 33.5 42.4 8.2 1.9 1.3 0.0 0.6 # (%)

The weight distribution supplied by SDDOT for "Double" trucks was used for class 12 trucks.

lengthDistrib: 0.0 0.0 0.0 0.0 0.0 0.0 26.4 36.8 36.8 0.0 # %

The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 13 7 or more axles, multi-trailer

weightRange: 70000 170000

weightDistrib: 0.0 0.0 0.0 0.0 11.1 22.2 11.1 11.1 22.2 22.3 # (%)

The weight distribution supplied by SDDOT for “7+ axle” trucks was used for class 13 trucks. The range is from 70,000 pounds to 170,000 pounds.

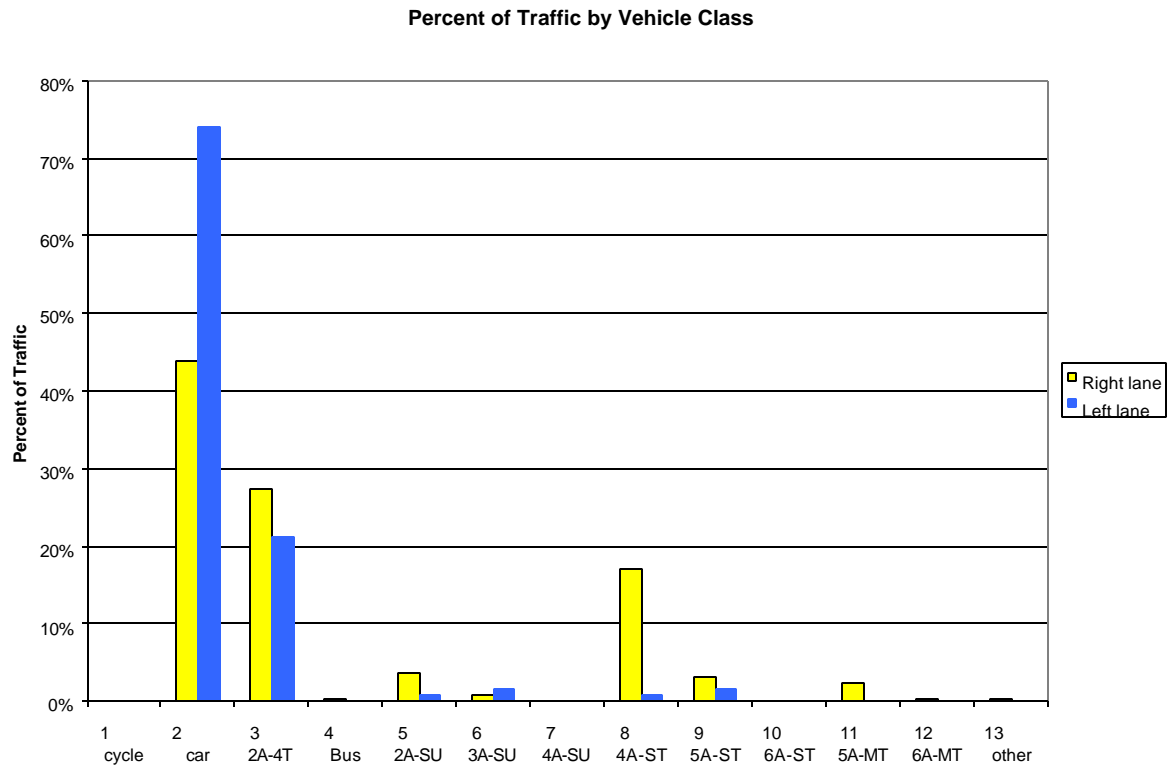
**lengthDistrib:** 0.0 0.0 0.0 0.0 0.0 0.0 26.4 36.8 36.8 0.0

The length distribution for this class and for all truck classes was supplied by SDDOT.

**ClassDistribution 2 origins**

Link	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13
0	0.0	44.6	27.4	0.3	3.5	1.0	0.0	17.0	3.1	0.1	2.3	0.4	0.3
1	0.0	74.0	21.2	0.0	0.8	1.6	0.0	0.8	1.6	0.0	0.0	0.0	0.0

Link 0 and link 1 are the two origin links, where vehicles enter the simulation. Link 0 represents the right lane of northbound I-29 and link 1 is the left lane. These lines in the input file specify the percentage of each vehicle class to enter the simulation on each link. The percentage of each class was taken from the data collected by SDDOT at the McCook facility in March 1998. SDDOT had set up counters in each lane approaching the station. Mitretek used the proportions of traffic in each lane from 10 a.m. to 11 a.m., consistent with the peak truck traffic times described previously. Figure 4-4 shows the percentage of each vehicle class. When links 0 and 1 are defined in the “LinkInfo” section, the percentage of total traffic entering the simulation on each of the two lanes is defined.



**Figure 4-4. Distribution of Vehicle Classifications by Lane on Northbound I-29**

#### [Attributes]

Each attribute (also called a characteristic) of a vehicle is determined at the time it enters the simulation. Some attributes are given other values during the simulation as a result of a test. The probability of each characteristic being set to true is specified. The probability may depend on the value of previously set attributes. The cab and/or trailer of a vehicle may be displayed in a certain color to indicate that a certain attribute is true. Attributes need not be defined in numerical order, and there may be gaps in the sequence of attribute numbers.

#	name	cab color	trailer color	%	expr	%	expr
#	----	-----	-----	---	-----	---	-----
1	"car"	yellow	yellow	100	{ c2 }		

Cars are displayed in yellow. 100% of the vehicles in class 2 are designated as cars.

2	"truck"	default	default	100	{ ( not c2 ) and ( not c3 ) and ( not c4 ) }		
---	---------	---------	---------	-----	--	--	--

Trucks are normally displayed with the default color (blue). If the vehicle is not class 2, class 3, or class 4, there is a 100% chance that the vehicle will be a truck (i.e. all vehicles that are not cars, pickup trucks, or buses are trucks). Pickup trucks (class 3) and buses (class 4) are not treated like trucks since they are not required to stop for inspection.

3	"overweight"	default	lightred		owt { }		
---	--------------	---------	----------	--	---------	--	--

This attribute is true if the vehicle is overweight (over 80,000 pounds). The special keyword "owt" indicates that this attribute is set by comparing the weight to the limit, rather than by drawing a new random value. Overweight trucks are displayed on the computer screen with red trailers.

4	"safety check"	default	black	2	{ 2 }		
---	----------------	---------	-------	---	-------	--	--

If attribute 2 is true (the vehicle is a truck), there is a 2% chance the vehicle will be pulled over for a safety check. This percentage was the percentage of trucks pulled over for safety reasons as reported by SDDOT. These trucks are displayed with black trailers.

5	"credential check"	lightred	default	4	{ 2 }		
---	--------------------	----------	---------	---	-------	--	--

If attribute 2 is true (the vehicle is a truck), there is a 4% chance the vehicle will be checked for credentials or logbook violations. This percentage was the percentage of trucks pulled over for credential checks as reported by SDDOT. Trucks suspected of credentials or logbook problems are displayed with red cabs (suggesting that the problem is with the driver, not the cargo).

6	"fixable"	default	default	100	{ 3 }	100	{ 5 }	90	{ 4 }
---	-----------	---------	---------	-----	-------	-----	-------	----	-------

100% of the trucks with weight (attribute 3) or credential problems (attribute 5) are considered "fixable" in that they are allowed back on the highway after a short time. 90% of the trucks with safety problems (attribute 4) are allowed to leave after the problem is fixed or noted. However, 10% of the unsafe trucks are placed out of service for the remainder of the simulation. These percentages come from data recorded at the McCook station over two days in June, where one unsafe truck was effectively placed out of service each day out of 9 or 10 unsafe trucks.

7	"inspected"	lightblue	lightblue	0	{ }		
---	-------------	-----------	-----------	---	-----	--	--

Initially all vehicles have this attribute set to false. However, the vehicles that have been pulled into the parking lot and then released have this attribute set to true, so they will not be counted as bad misses by test 7. Their color is restored to blue from whatever color it was to indicate that it may proceed back to the highway. Because of the order the attributes are defined, trucks with attribute 7 true are displayed with blue cabs and trailers, regardless of their previous colors.



8 "OOS"                      black        black            0 { }

Initially all vehicles have this attribute set to false. However, the trucks that are not fixable (10% of the unsafe trucks) are placed "out of service" and have this attribute set to true after inspection. They are displayed as all black, and they never leave the parking lot.

10 "held at scales"        default        default            50 { 3 }

According to SDHP, half the overweight trucks are held at the scales longer while the driver is summoned into the office to see the results of the scale measurement. 50% of the overweight trucks (attribute 3) have this attribute set to true. It is checked in the specification for service time 1.

12 "legal"        default        default        100 { 2 and ( not 3 ) and ( not 4 ) and ( not 5 ) }

This attribute is set to true for each truck of legal weight with no credential or safety problems. It is defined so that statistics on the average station transit time for these trucks can be computed and displayed. Overweight trucks and trucks with credential or safety inspections spend much longer in the simulation. These longer times should not be counted when determining how much delay is caused to legal trucks by the weighing operation.

15 "waved through"        default        lightgray        0 { }

This attribute is initially set to zero for all trucks. It is set to 1 if the truck is waved past the scales when the scales are temporarily shut down (see test 6). The trailers of these trucks are displayed gray.

16 "bad misses"            default        brown            0 { }

This attribute is set to true when a truck that is overweight or has safety or credential problems is waved past the scales when the scales are temporarily shut down (see test 7). It is defined so that the model can report the number of such trucks. The trailers of these trucks are displayed brown.

#### [Tests]

Each branch and parking lot link performs a test on each vehicle as it enters the link. The test is a Boolean combination of vehicle attributes. If the value of the test is true, the vehicle leaves the branch link by the alternate link (the second link named in the link file). If the value of the test is false, the vehicle leaves the branch by the main link (the first link named in the link file). More than one branch may perform the same test. If an attribute number is specified in the second part of the test, that attribute is set to true for all vehicles that pass the test.

1 "trucks right"            A { 2 } { }

All trucks (not including pickup trucks) take the alternate branch to the right. This test is used twice: first to move any trucks still in the left lane when the station is at hand (link 4) to the right lane (link 6), and then to move all trucks from the right lane onto the station entrance ramp (link 9).

2 "to parking lot"        A { 3 or 4 or 5 } { }

All trucks that are overweight (attribute 3) or unsafe (attribute 4) or have credentials problems (attribute 5) take the alternate branch from the scales toward the parking lot. All other trucks take the primary branch back to the highway. This test is applied by link 12 (the scale link). Trucks that have already been inspected bypass the scales on links 13, 14, and 15, so they are not inspected a second time.

3 "safety check"            A { not 6 } { 8 }

This test is performed in the parking lot (link 21). All vehicles that are not fixable (not attribute 6) are tagged with attribute 8 (out of service). Those trucks will not leave the parking lot. Otherwise, after waiting the appropriate length of time, they return to the highway.

4 "fix some"                      A { 6 } { 7 }

Trucks leaving the parking lot go through a branch (link 22) with this test. Since all vehicles leaving the parking lot are fixable, no trucks fail this test. In fact, both exit links are the same. The only purpose of this test is to set attribute 7 (inspected) to true for those trucks, so are not counted as bad misses by test 7.

6 "missed truck"                    A { 2 } { 15 }

Links 12 and 16 are defined as occupying the same physical space. Link 12 contains a static scale and link 16 does not. When the scales are closed because of queue backup, link 12 closes, and trucks are switched to link 16. Thus the only time a truck traverses link 16 is when the scales are closed. Therefore all trucks on link 16 have attribute 15 (waved through) set to true.

7 "bad miss"                        A { 15 and ( 3 or 4 or 5 ) and ( not 7 ) } { 16 }

This attribute is set to true whenever a truck that is overweight truck (attribute 3) or has safety (attribute 4) or credential (attribute 5) problems has been waved by the scale (attribute 15) and has not already been inspected (not attribute 7). These are the trucks that should have been inspected but were not because of station congestion.

#### [ServiceTimes]

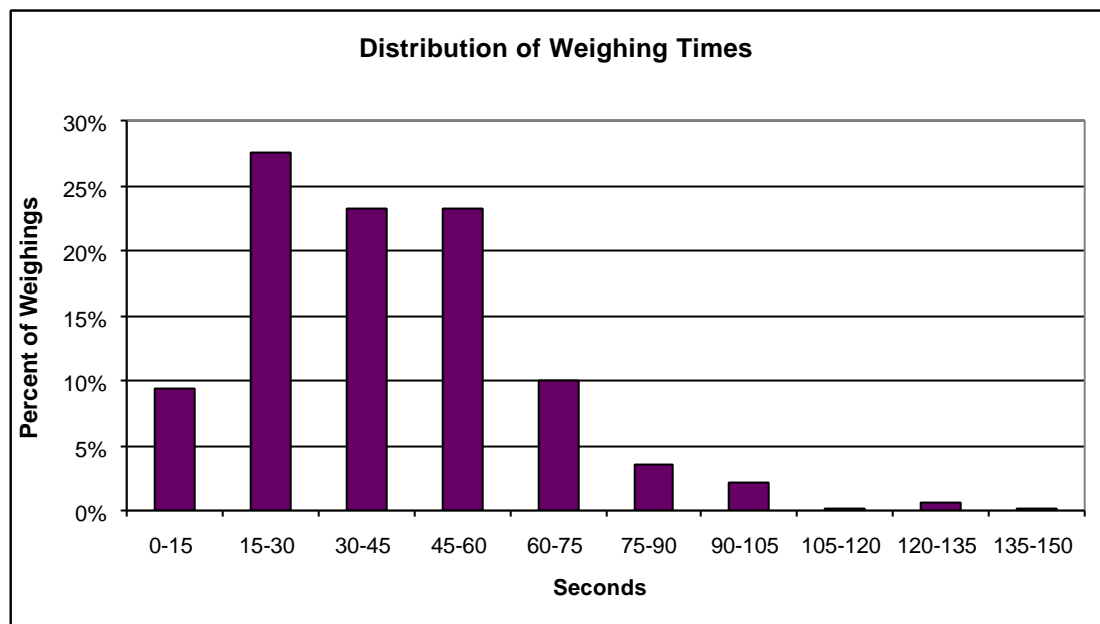
Service times are specified for scales and branches as probability distributions. Different distributions may be specified for different Boolean combinations of vehicle classes. The types of possible distributions are Normal, Uniform, Erlang, or Constant.

#	name	expression	random type	parms
#	----	-----	-----	-----
1	"weighing time"	{ 10 }	Erlang	90 { } Erlang 41

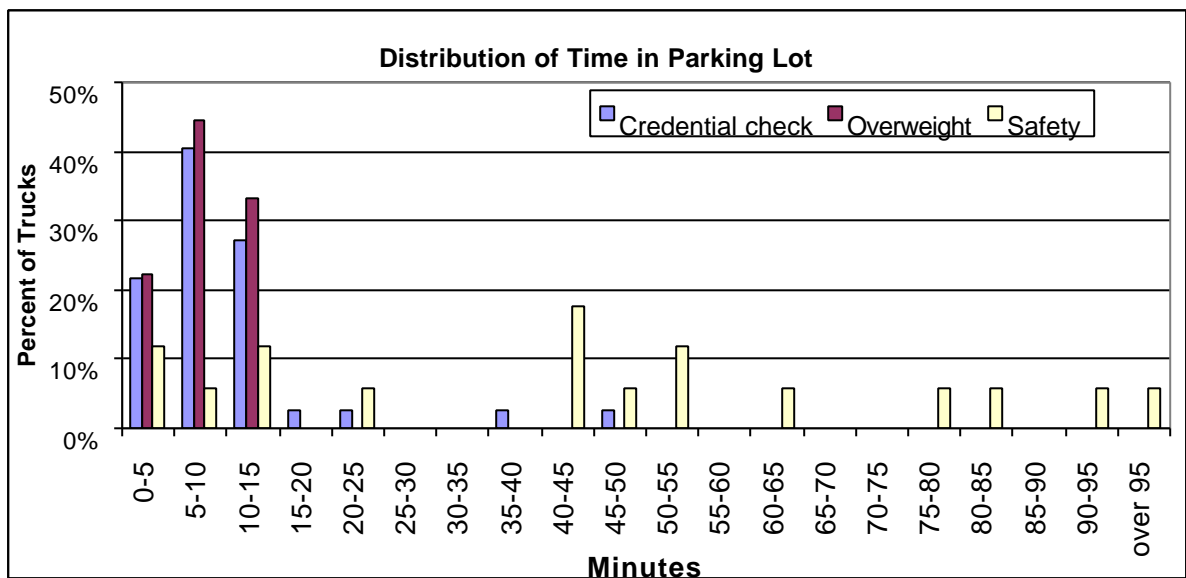
The service time distribution was calculated from data recorded at the McCook station by SDDOT on June 15 and 16, 1998. In all, 665 observations were recorded, grouped by 15-second intervals. The distribution of this data is shown in figure 4-5. The plot suggests that the distribution of service times is consistent with an Erlang distribution (see figure 2-6). The average value is 41 seconds. However, for trucks with attribute 10 true (held at scales) the service time was 90 seconds, reflecting the extra time for the driver to be shown the scale measurement.

2 "inspection time" { 5 } Erlang 900 { 4 } Erlang 3000 { 3 } Erlang 1200 # sec.

SDDOT recorded the time spent in the parking lot for 67 trucks on June 15 and 16, 1998. The arrival and departure time for each truck was recorded, together with an indication of the reason for detention. Mitretek grouped the overweight, safety, and credential-related causes separately and computed the average time for each one. The results are presented in figure 4-6. Although the number of observations is not large, the data are consistent with the assumption of an Erlang distribution of service time in the parking lot.



**Figure 4-5. Distribution of Time between Trucks on Scale at McCook**

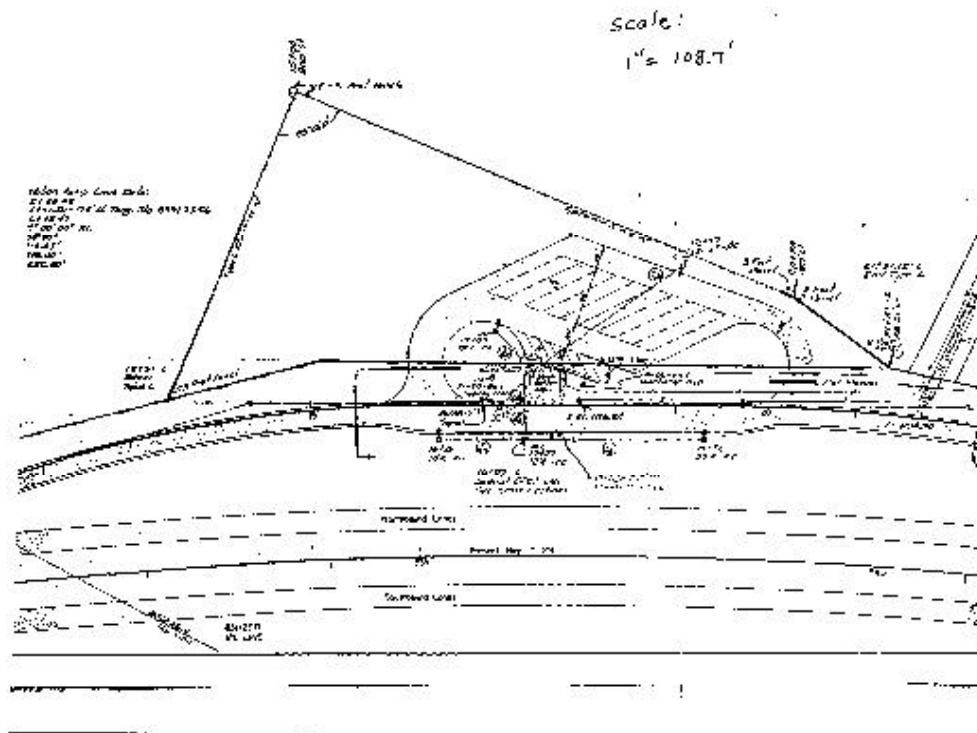


**Figure 4-6. Distribution of Time in Parking Lot**

[LinkInfo]

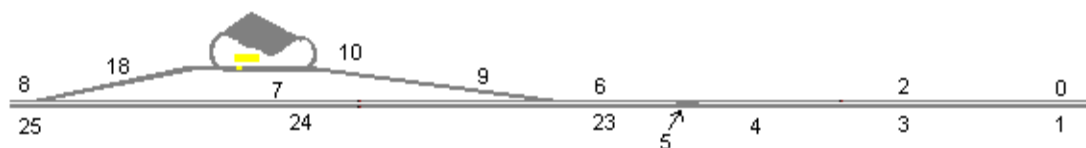
This section specifies information for each link in the simulation. The first column is the link number. The second column gives the type of link. The third and fourth columns specify the first and second

links following the given link. Two exit links are specified only if the link is a branch or scale; otherwise there is a dash (-). The fifth column specifies the free speed limit in miles per hour. The sixth and seventh columns specify the x and y coordinates (in feet) of the start of the link and the eighth and ninth columns specify the x and y coordinates of the end of link. Mitretek determined the link coordinates from the scale drawing of the McCook facility provided by SDDOT, shown in figure 4-7.

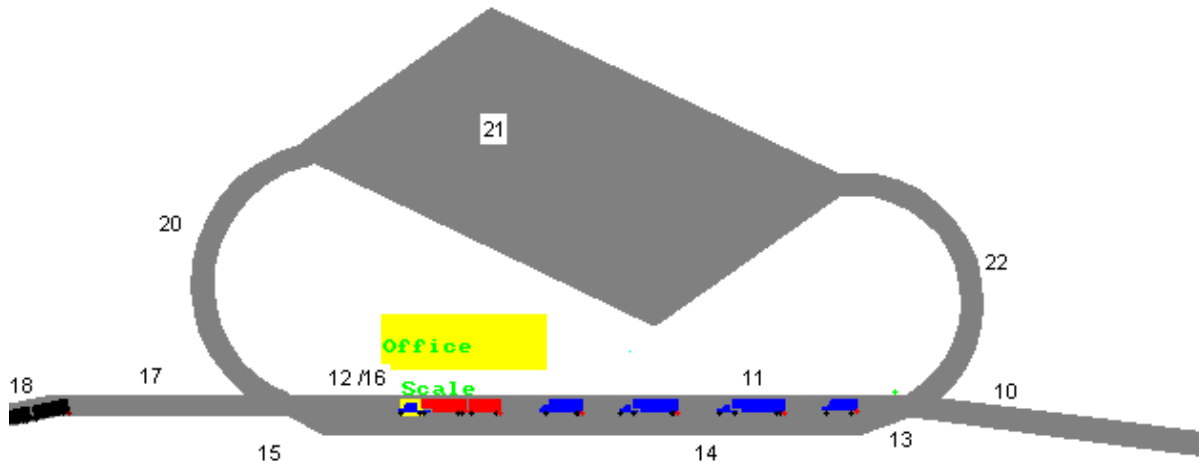


**Figure 4-7. Scale Drawing of McCook Station from SDDOT**

Notes on individual links follow the listing. Figure 4-8 provides an overview of the station as modeled in Westa, showing link numbers. Figure 4-9 presents a close-up of the central weighing and inspection area. Table 4-3 presents the special characters used to specify link options in the linkinfo section. Table 4-4 presents the LinkInfo section of the base case data file.



**Figure 4-8. Overview of McCook Station on Northbound I-29**



**Figure 4-9. Detail of Central Area of McCook Station**

Code	Explanation
T	Precedes the test number for a branch link
ST	Precedes the service time number for a branch or scale link
Y	Indicates that traffic on that link must yield when merging with traffic from another link
CC	Precedes the coordinates of the center of curvature for a curved link
PS	Precedes the number of parking spaces for a parking lot
OC	Precedes the x and y coordinates of the opposite corner of a parking lot (the corner directly opposite the corner where trucks enter the lot)
NQ	Specifies that no queuing applies in the parking lot (service time starts as soon as the truck parks, rather than waiting for any other trucks in the lot)
A	Indicates the proportion of arrivals to appear on each origin link
AS	Exit from the link is governed by an actuated signal keyed on the designated link
CL	The link is closed when the designated link reaches the closing threshold (see “C” ) and reopens when the designated link reaches the reopening threshold (see “O”)
C	The link closes when the ratio of total truck length to total link length exceeds this fraction
O	The link reopens when the ratio of total truck length to total link length drops below this fraction
LL	Indicates the link number of the corresponding left-hand lane where lane-changing is permitted
RL	Indicates the link number of the corresponding right-hand lane where lane-changing is permitted
Q	The number of trucks in this link is to be included in the queue length count
SC	Indicates that when this link is closed, the station is closed (the simulation keeps track of how long the station is closed).

### Table 4-3. Special Link Options in the LinkInfo Section

[LinkInfo]												
#	type	ahead	spd	dimensions				typespecific				
#	----	--	--	---	-----				-----			
0	Orig	2	-	55	4400	100	3900	100	A	.8	LL	1
1	Orig	3	-	55	4400	80	3900	80	A	.2	RL	0
2	Trans	6	-	55	3900	100	2700	100	LL	3		
3	Trans	4	-	55	3900	80	3200	80	RL	2		
4	Branch	23	5	55	3200	80	2800	80	T	1		
5	Trans	6	-	55	2800	80	2700	100	Y			
6	Branch	7	9	55	2700	100	2200	100	T	1	LL	24
7	Trans	8	-	55	2200	100	100	100	LL	25		
8	Dest	-	-	55	100	100	0	100				
9	Trans	10	-	35	2200	100	1300	217	Q			
10	Trans	11	-	15	1300	217	1200	230	Q	AS	22	
11	Branch	16	12	10	1200	230	920	230	T	1	Q	
12	Branch	17	20	5	920	230	860	230	ST	1	T	2
13	Trans	14	-	10	1200	230	1170	220				
14	Trans	15	-	10	1170	220	880	220				
15	Trans	17	-	25	880	220	860	230	Y			
16	Branch	17	17	10	920	231	860	231	T	6		
17	Branch	18	18	35	860	230	730	230	T	7		
18	Trans	8	-	55	730	230	100	100	Y			
20	Trans	21	-	10	860	230	870	370	CC	882	297	
21	Park	22	22	5	870	370	1160	350	ST	2	T	3
22	Branch	13	13	10	1160	350	1200	230	T	4	CC	1170
23	Trans	24	-	55	2800	80	2700	80				
24	Trans	25	-	55	2700	80	2200	80				
25	Dest	-	-	55	2200	80	0	80				
40	Bldg	-	-	0	910	250	1000	280	"Office"			
41	Bldg	-	-	0	920	224	932	234	"Scale"			

**Table 4-4. Base Scenario LinkInfo Section**

Links 1, 3, 4, 23, 24, and 25 are the left lane of Northbound I-29. Link 1 is the origin link, delivering 20 percent of the vehicles. Link 3 is a long transit link. Any trucks on link 3 may shift right to link 2 if there is sufficient room. Cars may switch lanes at will, given a sufficient gap, but trucks may only shift to the right lane from the left lane.

All trucks that haven't shifted to the right lane by the end of link 4 must take the branch (link 5), which merges with link 2 into link 6 (changes from the left lane to the right lane). Traffic on link 5 yields to traffic on link 2. Cars, buses, and pickup trucks on link 4 continue on to links 23, 24, and 25, bypassing the weigh station. Vehicles completing destination link 25 exit the simulation.

Links 0, 2, 6, 7, and 8 are the right lane of northbound I-29. Link 0 is the origin link, delivering 80 percent of the vehicles. Cars, buses, and pickup trucks on links 2, 6, and 7 may change lanes to the left onto links 3, 24, 25 respectively if there is enough space. Link 6 is the branch link in the right lane. At the end of this branch, all trucks must exit the highway into the station on the ramp link 9. Cars and pickup trucks continue on highway link 7. Vehicles completing destination link 8 exit the simulation.

Link 9 is the ramp into the station, leading to link 10. There is an actuated signal defined for link 10. Whenever a truck is exiting the parking lot on link 22, the actuated signal turns red, forcing trucks on link 10 to wait for the emerging truck. At all other times the signal is green.

Link 11 is just before the scales. Link 11 sends all trucks to the scales (link 12), unless link 12 is closed, in which case link 11 sends all traffic to the other defined branch (link 16). Link 16 and link 12 are defined in the same physical location. However, link 16 does not require trucks to stop. Instead, it uses test 6 to set attribute 15 true for any trucks crossing it. Thus this link models the operation of the station when the scales are closed.

Link 12 is the scale where test 2 is applied (is the truck overweight or is there a reason for a safety or credential check?) If any of these are true, the truck takes the right branch (link 20) to the parking lot. If no further check is required, the truck takes the left branch (link 17) toward the station exit. Service time 1 defines the distribution of times to weigh a truck and make the safety/credential determination. The parameters for link 12 specify that when link 9 is more than 50% full, link 12 closes. The percentage full is computed by dividing the length of trucks on the link to the link length. Mitretek has found that this procedure detects when the ramp is full of trucks better than judging whether a truck over a loop detector is stopped at the end of the queue or not. When link 12 is closed, link 11 directs all trucks to link 16, which occupies the same space as link 12, but does not require trucks to stop. When the length of trucks on link 9 is reduced to 20% of its length, the scale reopens, and trucks again enter that link.

The definitions for links 9, 10, and 11 include a “Q”. This tells the model to sum the number of trucks on these three links to compute the current queue length.

The scale departure link (link 17) leads to the reentry ramp onto the highway (link 18). Trucks on link 18 must yield to highway traffic on link 7, as both links merge onto link 8.

Links 13, 14, and 15 bypass the static scale. Trucks emerging from the parking lot go directly to link 13, bypassing the scale. Link 15 merges with link 16 onto link 17. Traffic on link 15 yields to traffic on link 16.

The ramp to the parking lot (link 20) leads to the parking lot (link 21). In the parking lot, test 3 (safety inspection) is applied. Service time 2 defines the distribution of times to perform a safety, credential, or weight distribution inspection and to fix the problem. If the truck is fixable, after waiting the appropriate time, it exits the lot on the parking lot exit ramp (link 22). On link 22, the truck’s attribute 7 (inspected) is set to true and the truck goes to link 13 so it is not pulled over at the scales a second time.

Links 40 and 41 are not links at all, but are simply labeled locations shown on the display. Link 40 is the office and link 41 is the scale.

#### [GraphInfo]

The following lines define the statistics boxes in the lower left corner of the screen. The first four statistics display the current cumulative count of vehicles with certain attributes. A vehicle does not get counted in these statistics until it leaves the simulation, either by exiting a destination link or by being placed out of service in the parking lot. The fifth statistic displays the cumulative average transit



time for all underweight trucks with no credential or safety problems that finish the simulation. The last statistic gives the total number of trucks in links defined with a “Q” (i.e. links 9, 10, and 11).

```
Stat  "Total number of trucks" Count 2
Stat  "Overweight trucks"      Count 3
Stat  "Waved through"          Count 15
Stat  "Violators missed"       Count 16
Stat  "Average time"           Time 12
Stat  "Trucks in queue"        QueueLen
```

The following lines define six “views”. These are preset coordinates that can be invoked by pressing a single number key during the simulation.

```
View 1  1817  2857 -237  545
View 2  1160  2701 -237  545
View 3   784  1317   57  457
View 4    48   881  -96  529
View 5   888  1107  135  298
View 6  4160  4501  -36  221
```

[End]

Note: other data collected at the McCook station, including number of trucks in queue, frequency of queue overflow, and number of trucks in the parking lot were not used as input. Instead they were used for validating the output of the model.

### 4.3 First Alternate Scenario

At the request of SDDOT and SDHP, Mitretek modeled the operation of a proposed station to replace the current McCook facility. The station layout would be similar to the existing layout, except for the addition of a low-speed WIM scale on the station entrance ramp and a bypass lane between the scale facility and the highway. A variable message sign following the WIM scale would direct trucks weighed over a certain threshold to proceed to the static scale, and would direct trucks weighed under that threshold to use the bypass lane. A branch from the bypass lane to the parking lot would enable the station operator to direct trucks with possible safety or credential problems to the inspection lot. Figure 4-10 shows how Westa represents the different configuration.

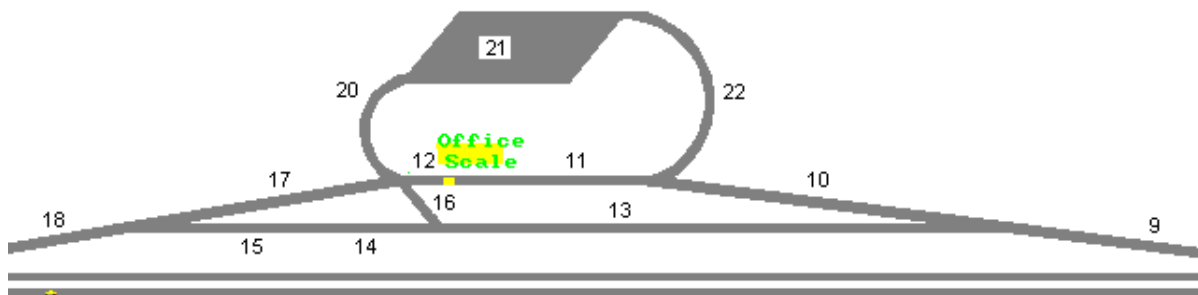


Figure 4-10. Proposed Weigh Station with WIM Scale and Bypass Lane

SDHP further specified that not all trucks weighed over the threshold would be directed to the station scale. Most overweight trucks have special permits granting permission to travel the highway or have extra axles to spread out the extra weight so that the maximum weight per axle is not violated. SDDOT plans to direct a randomly chosen 10 percent of overweight trucks to the static scale for weighing, plus all trucks that are over the maximum axle weight limitations as well as over the gross weight threshold. Data were not available defining the proportion of trucks exceeding gross weight of 80,000 pounds that also exceeded axle weight limitations. As a lower bound, Mitretek assumed a value of 10 percent. Thus 20 percent of the trucks over 80,000 gross weight were sent to the static scales and all other trucks were allowed to bypass the scales.

The first alternate scenario was modeled with the following changes in the input file. First, a new attribute was defined named "axle weight/random." Since ten percent of the trucks over 80,000 pounds gross weight were assumed to be in violation of maximum axle weight limitations, and ten percent of the same group of trucks were randomly selected for weighing, twenty percent of the overweight trucks had this attribute.

```
11 "axle weight/random"    default    default    20 { 3 }
```

A new test was defined to check for this attribute.

```
5 "axle or random"        A { 11 } { }
```

Test 7 was added so that trucks with credential or safety problems could be detected in the bypass lane and sent to the parking lot for inspection. Test 8 was defined to mark trucks that took the bypass lane, and test 9 was defined to mark overweight trucks that took the bypass lane.

```
7 "to parking lot2"       A { 4 or 5 } { }
8 "set bypass"            A { 2 } { 14 }
9 "set heavy bypass"      A { 3 } { 16 }
```

Next, the station entrance ramp (link 9) was changed from a transit link to a branch link. It applied test 5. All trucks with attribute 11 true were sent to the static scale as before. All other trucks were sent to the new bypass link 13. Link 13 is itself a branch, applying test 7. All trucks with safety or credential concerns were directed to link 16 toward the parking lot. Other trucks proceeded to link 14, where their attribute 14 (bypass) was set to true by test 8. On link 15, overweight trucks had their attribute 16 (overweight bypass) set to true by test 9.

```
9 Branch 13 10 35 2200 100 1700 165 T 5
13 Branch 14 16 35 1700 165 915 165 T 7
14 Branch 15 15 35 915 165 600 165 T 8
15 Branch 18 18 35 600 165 480 165 T 9
```

Trucks on link 15 merged with trucks on link 17 onto the highway reentry link (link 18).

#### 4.4 Second Alternate Scenario

After running the previous scenario, Mitretek noted that there was significant unused capacity at the static scales. In fact, the scales were empty most of the time. This unused capacity could be used by the station operators to conduct more thorough safety inspections. On the other hand, it might be

possible to weigh more trucks without causing congestion. Therefore Mitretek changed the operating policy suggested by SDDOT, so that all trucks measured by the WIM scale as over 70,000 pounds would be sent to the static scales, rather than 20%. This scenario is an upper bound on the number of trucks sent to the static scales from a WIM scale.

Since a measurement from a WIM scale is not as accurate as a measurement from a static scale, the threshold for sending a truck to the static scale is typically set less than the legal weight limit. For this scenario, Mitretek set the threshold at 70,000 pounds, and assumed the WIM scale had a 5% error rate. This means that the weight of a truck passing over the scale was measured as its simulated weight plus or minus a random number drawn from a normal distribution with mean equal to zero and standard deviation equal to 5% of the simulated weight. The station entry ramp (link 9) was changed from the branch link of the first alternate scenario to a scale link with threshold 70,000 and error .05.

```
9  Scale  13 10  35  2200  100 1700  165  W 70000 E .05
```

#### 4.5 Increased Traffic Scenarios

At the request of SDDOT, Mitretek ran each of the three scenarios again with the traffic load increased by 20% and by 30%. A fact sheet from the trucking industry's Team 2000 predicts that "In the year 2006 ... the total number of miles driven [by trucks] will have grown by 28% and the total volume of ton-miles will have grown by 32%." The only change to the input files for the three scenarios was the decrease in vehicle interarrival time, which increased the hourly number of arrivals by 20% or by 30%. The arrival rate for each class of vehicles increased proportionately by the same amount.

avgCreatTime:	8.33	# 20% increase
avgCreatTime:	7.69	# 30% increase



## Section 5

# Representation of the Lehi Weigh Station Scenarios

This section describes and documents the Lehi weigh station base case configuration, three alternate configurations, and the sixteen scenarios based on the four configurations.

### 5.1 Description of Configurations and Scenarios

The base case configuration was constructed using data defining current station design and operation. The results of the simulation run with the base case configuration and the base percentage of trucks with transponders can be compared to current conditions at the station. Section 5.2 documents the input file for the base case configuration.

The first alternate configuration features dual static scales. All trucks directed to the static scale by the low-speed WIM scale on the station entrance ramp have the choice of proceeding to the scale on the left or the scale on the right. As modeled, trucks will choose the scale with the shortest queue. In all other respects the operation of the station is the same. The input file for this configuration is documented in section 5.3.

The second alternate configuration represents the addition of a high-speed WIM scale on the highway mainline before trucks reach the station. The station layout is the same as the existing layout. All trucks that do not exceed the maximum weight for any axle and that also have a transponder are permitted to remain on the highway, bypassing the station. All other trucks must enter the station as usual. The input file for this configuration is documented in section 5.4.

The third alternate configuration is a combination of the first and second alternate configurations. The configuration features both a mainline WIM scale and dual static scales. The input file for this configuration is documented in section 5.5.

All four configurations (the base case and the three alternate configurations) were modeled with four levels of truck transponder equipage. The base percentage is the current 12% noted by AHTD. Alternate cases were run where 20%, 30% and 40% of the trucks have transponders. Each combination of a configuration and a transponder level is called a scenario. In all, sixteen scenarios were modeled. Table 5-1 summarizes the sixteen scenarios.

Transponder %	Base Case	Dual Static Scale	Mainline WIM	Combination
12 %	X	X	X	X
20 %	X	X	X	X
30 %	X	X	X	X
40 %	X	X	X	X

**Table 5-1. Scenarios Modeled**

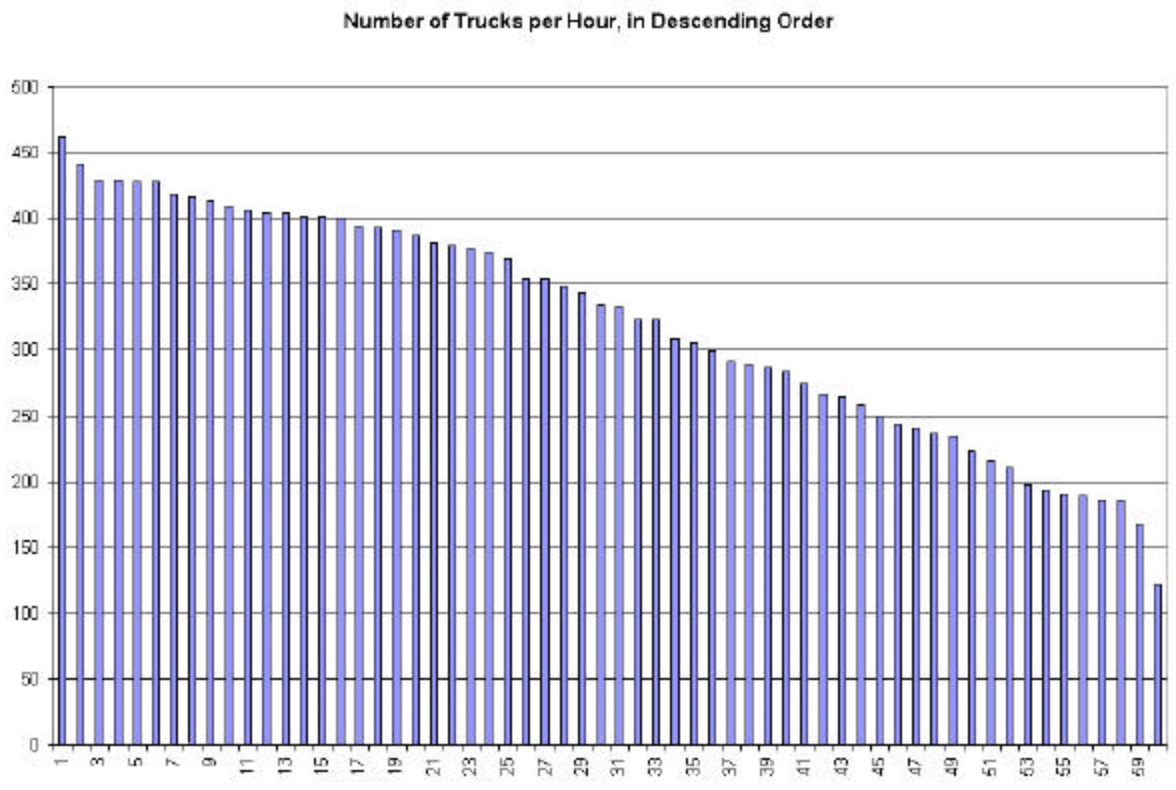


randomSeed\_truck: 101  
randomSeed\_link: 11

These random seeds initialize the random number generators for vehicle generation and weighing/inspection times. The numbers here were used for the first iteration. Mitretek ran each scenario ten times with a different pair of random seeds for each iteration, and averaged the results together for the results presented in Section 8.

avgCreatTime: 3.72 # (sec.)

A vehicle is generated every 3.72 seconds on the average. Mitretek obtained this figure from hourly traffic figures collected by the Crittenden County WIM station for 5/18/98 through 5/21/98. There were sixty hours of data during those three days. Figure 5-2 shows the number of trucks each hour, in descending order. Mitretek considered the busiest ten percent of the recorded traffic to be the peak traffic level. Table 5-2 shows the day and hour of the busiest six hours, and the number of vehicles in each FHWA category. During those six hours, the average total number of vehicles was 967, approximately one every 3.72 seconds. Since 45% of the vehicles during those hours were trucks, a truck is generated on the average every 8.3 seconds, for an arrival rate of 435 trucks of classes 5 through 13 per hour.



**Figure 5-2. Number of Trucks per Hour, May 19 – May 21, 1998**

Both lanes eastbound		FHWA Vehicle Class													Total	Total	Grand
Day	Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	non-trucks	trucks	Total
5/21/98	10	0	341	156	11	30	5	0	3	388	1	14	18	3	508	462	970
5/20/98	11	0	361	162	9	32	6	0	3	355	4	17	23	1	532	441	973
5/19/98	13	0	332	172	8	22	2	0	2	361	0	22	20	0	512	429	941
5/20/98	17	0	454	192	11	25	10	0	5	335	4	18	32	0	657	429	1086
5/19/98	10	0	324	169	14	30	8	1	4	339	2	25	17	2	507	428	935
5/19/98	11	0	314	150	10	44	2	0	5	335	3	18	19	2	474	428	902

**Table 5-2. Vehicle Statistics for Six Hours with the Most Trucks**

**maxWt:** 80000 # <- maxWt for static scales

The maximum legal gross weight for trucks without a special permit is set at 80,000 pounds per Arkansas regulations. Trucks with gross weight more than 80,000 pounds are considered overweight.

**TimeStep .2**

The size of the time step was reduced from one second to 0.2 second to enable detailed modeling of vehicle response to potentially hazardous situations. Driver perception-reaction times vary from 0.8 to 2.4 seconds, and vehicles have a corresponding lag in their behavior. Time steps as small as 0.2 seconds are required to model the effects of these different perception-reaction times.

**[TruckInfo]**

The following groupings define the distribution of length, weight, and acceleration/ deceleration characteristics for vehicles in each FHWA class. When values for any of these variables are not specified for a class, Westa uses values for the preceding class.

**Class 2 Cars**

**maxAccRange:** 2.8 6.3 .009 # (mi/hr/sec)

The maximum acceleration rate for each car is chosen from a uniform distribution between 2.8 and 6.3 mph per second. These values reflect the range of maximum acceleration capabilities for passenger cars reported in the Road Test Digest of Car and Driver magazine. Those acceleration figures are divided by two since the maximum acceleration used on a freeway is less than the maximum value on a test track. The value of 0.009 indicates that the maximum acceleration rate declines at .009 times the current speed (the faster a car is going, the smaller is its maximum acceleration).

**maxDecRange:** 17.3 20.7 .30 # (mi/hr/sec)

The maximum deceleration rate for each car is chosen from a uniform distribution between 17.3 to 20.7 mph per second. These values are the weighted averages plus and minus two standard deviations for maximum deceleration rates for passenger cars published in Consumer Reports magazine. The value of 0.3 indicates that the normal (comfortable) rate of deceleration is 0.3 times the maximum rate.

**weightRange:** 0 6000 # (lbs)

**weightDistrib:** 0.0 0.0 4.1 9.9 31.4 27.3 14.9 6.6 4.1 1.7 # (%)

The minimum and maximum weights serve as end points for the weight distribution. The weight range is divided into ten bins of equal size between the minimum and maximum value, and the percentages give the percent of cars in each bin. In this case, the bin size is 600 pounds. The values of weight distribution for cars reflect the weight range of new cars reported in Consumer Reports magazine. The weight of cars is irrelevant to the Lehi model in any case.





lengthRange: 10 20 # (ft)  
lengthDistrib: 0.0 0.0 1.7 7.4 19.0 28.9 27.3 10.7 5.0 0.0 # %

The minimum and maximum lengths serve as end points for the weight distribution. The length range is divided into ten bins of equal size between the minimum and maximum value, and the percentages give the percent of cars in each bin. In this case, the bin size is 1 foot. The values of length distribution for cars reflect the length range of new cars reported in the March 1998 Consumer Reports magazine.

Class 3 2-axle 4-tire (Pickup trucks)  
maxDecRange: 16.8 18.6 .30 # (mi/hr/sec)

The maximum deceleration rate for light trucks ranges from 16.8 to 18.6 mph per second. These values are the weighted averages plus and minus two standard deviations for maximum deceleration rates for light trucks published in Consumer Reports magazine. The value of 0.3 indicates that the normal (comfortable) rate of deceleration is 0.3 times the maximum rate.

lengthDistrib: 0.0 0.0 96.2 0.0 0.2 1.5 1.9 0.3 0.0

The length distribution for this class and for all truck classes was supplied by the South Dakota Department of Transportation (SDDOT). Mitretek assumed that the distribution of truck length for FHWA-defined vehicle classes is the same in Arkansas as in South Dakota, so the same values were used. Since the maximum and minimum lengths are not specified, the values for the previous class are used. Similarly, since the acceleration and weight characteristics of class 3 trucks are not specified, the values for cars are used. The weight of pickup trucks is irrelevant to the model in any case since they are not inspected.

Class 4 Buses  
maxDecRange: 16.8 18.6 .30  
lengthRange: 30 40  
lengthDistrib: 0.0 0.0 96.2 0.0 0.2 1.5 1.9 0.3 0.0

The same deceleration characteristics were used for buses as for small trucks. The distribution of bus lengths came from SDDOT. Bus characteristics are not significant to the Lehi model since they are not inspected.

Class 5 2-axle 6-tire single units

The performance characteristics of class 5 trucks were assumed to be the same as for light trucks so they are not specified.

weightRange: 0 100000  
weightDistrib: 0.7 71.0 18.5 6.9 1.9 0.7 0.3 0.0 0.0 0.0

The weight distribution for this and all truck classes was taken from the distribution of weights collected by WIM at the Crittenden County site. Table 5-3 presents the distribution of weights across vehicle classes 5 through 13.

lengthRange: 0 50 # (ft)  
lengthDistrib: 0.0 2.4 64.1 23.6 9.9 0.0 0.0 0.0 0.0 0.0

The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 6 3-axle single units  
maxAccRange: 1.3 2.6 .009 # (mi/hr/sec)

The maximum acceleration rate for each large truck (class 6 and above) is chosen from a uniform distribution between 1.3 and 2.6 mph per second. These values range around the value of .1g (2.2 mph) considered good acceleration for a loaded truck. The value of 0.009 indicates that the maximum acceleration rate declines at .009 times the current speed (the faster a truck is going, the smaller is its maximum acceleration).

Bin	Straight Class 5	3-axle Class 6	4-axle Class 7	Trailer Class 8	5-axle Class 9	6-axle Class 10	Double Class 11	Double Class 12	7+-axle Class 13
0-10K	0.007	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10-20K	0.710	0.358	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20-30K	0.185	0.340	0.023	0.023	0.141	0.051	0.109	0.073	0.000
30-40K	0.069	0.119	0.045	0.045	0.162	0.073	0.120	0.118	0.134
40-50K	0.019	0.060	0.091	0.091	0.146	0.112	0.193	0.168	0.053
50-60K	0.007	0.075	0.545	0.545	0.135	0.170	0.229	0.201	0.160
60-70K	0.003	0.027	0.204	0.204	0.177	0.194	0.186	0.155	0.213
70-80K	0.000	0.007	0.000	0.000	0.124	0.176	0.070	0.149	0.213
80-90K	0.000	0.006	0.023	0.023	0.052	0.120	0.043	0.078	0.120
90-100K	0.000	0.002	0.023	0.023	0.024	0.062	0.025	0.037	0.013
100-110K	0.000	0.000	0.000	0.000	0.014	0.027	0.018	0.014	0.027
110-120K	0.000	0.000	0.046	0.046	0.025	0.015	0.007	0.007	0.027
120-130K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.040

**Table 5-3. Distribution of Truck Weights by FHWA Class**

**maxDecRange:** 12.8 16.0 .30 # (mi/hr/sec)

The maximum deceleration rate for trucks ranges from 12.8 to 16.0 mph per second. The upper value was supplied by data in the American Trucking Association library. The lower value was based on the assumption that some trucks will have less than optimal brakes. The value of 0.3 indicates that the normal (comfortable) rate of deceleration is 0.3 times the maximum rate.

**weightRange:** 0 100000 # (lbs)

**weightDistrib:** 0.6 35.8 34.0 11.9 6.0 7.5 2.7 0.7 0.6 0.2 # The weight distribution for this and all truck classes was taken from the distribution of weights collected by WIM scale at the Crittenden County site.

**lengthRange:** 0 50

**lengthDistrib:** 0.0 0.0 0.8 18.7 72.3 8.2 0.0 0.0 0.0 0.0 # %

The length distribution for this class and for all truck classes was supplied by SDDOT.

**Class 7 4 or more axles, single unit**

**weightRange:** 0 100000

**weightDistrib:** 2.3 4.5 9.1 54.5 20.4 0.0 2.3 2.3 0.0 4.6 # (%)

The weight distribution for this and all truck classes was taken from the distribution of weights collected by WIM scale at the Crittenden County site.

**lengthDistrib:** 0.0 0.0 0.0 11.5 50.0 34.6 3.8 0.0 0.0 0.0 # %

The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 8 4 or fewer axles, single trailer

weightRange: 0 100000

weightDistrib: 2.3 4.5 9.1 54.5 20.4 0.0 2.3 2.3 0.0 4.6 # (%)

The weight distribution for this and all truck classes was taken from the distribution of weights collected by WIM scale at the Crittenden County site.

lengthRange: 20 70 # (ft)  
lengthDistrib: 0.0 6.8 22.4 35.1 16.4 7.4 6.5 4.2 1.1 0.0 # %  
The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 9 5-axle, single trailer  
weightRange: 200000 120000  
weightDistrib: 14.1 16.2 14.6 13.5 17.7 12.4 5.2 2.4 1.4 2.5 # (%)  
The weight distribution for this and all truck classes was taken from the distribution of weights collected by WIM scale at the Crittenden County site.

lengthRange: 35 85  
lengthDistrib: 0.2 0.6 2.1 10.0 37.1 46.0 3.9 0.2 0.0 0.0 # %  
The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 10 6 or more axles, single trailer  
weightRange: 20000 120000  
weightDistrib: 5.1 7.3 11.2 17.0 19.4 17.6 12.0 6.2 2.7 1.5 # (%)  
The weight distribution for this and all truck classes was taken from the distribution of weights collected by WIM scale at the Crittenden County site.

lengthRange: 20 90  
lengthDistrib: 0.0 0.0 0.9 8.8 31.0 27.9 27.4 3.5 0.4 0.0 # %  
The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 11 1.1 % 5 or fewer axles, multi-trailer  
weightRange: 20000 120000  
weightDistrib: 10.9 12.0 19.3 22.9 18.6 7.0 4.3 2.5 1.8 0.7 # (%)  
The weight distribution for this and all truck classes was taken from the distribution of weights collected by WIM scale at the Crittenden County site.

lengthRange: 20 90#  
lengthDistrib: 0.0 0.0 0.9 8.8 31.0 27.9 27.4 3.5 0.4 0.0 # %  
The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 12 6 axles, multi-trailer  
weightRange: 20000 120000  
weightDistrib: 13.4 5.3 16.0 21.3 21.3 12.0 1.3 2.7 2.7 4.0 # (%)  
The weight distribution for this and all truck classes was taken from the distribution of weights collected by WIM scale at the Crittenden County site.

lengthDistrib: 0.0 0.0 0.0 0.0 0.0 0.0 26.4 36.8 36.8 0.0 # %  
The length distribution for this class and for all truck classes was supplied by SDDOT.

Class 13 7 or more axles, multi-trailer  
weightRange: 70000 170000  
weightDistrib: 0.0 0.0 0.0 0.0 11.1 22.2 11.1 11.1 22.2 22.3 # (%)  
The weight distribution for this and all truck classes was taken from the distribution of weights collected by WIM scale at the Crittenden County site.

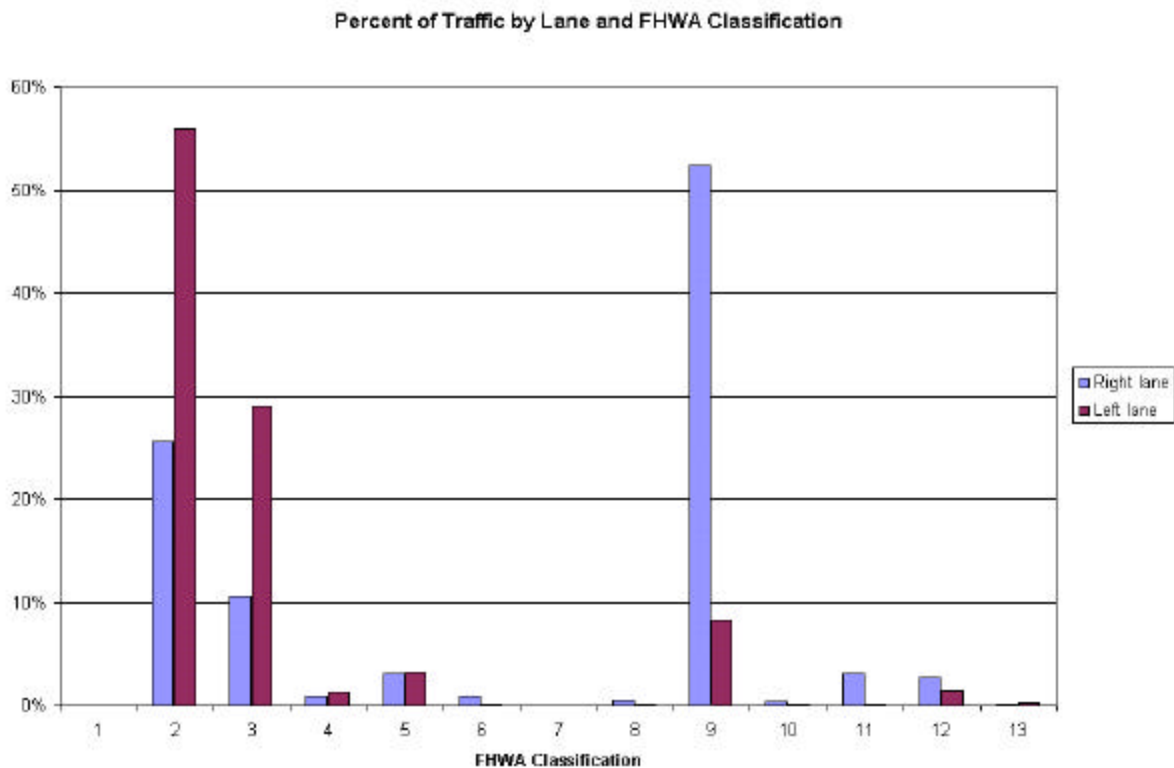
lengthDistrib: 0.0 0.0 0.0 0.0 0.0 0.0 26.4 36.8 36.8 0.0

The length distribution for this class and for all truck classes was supplied by SDDOT.

#### ClassDistribution 2 origins

Link	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13
3	0.0	25.7	10.5	1.0	3.1	0.8	0.0	0.5	52.3	0.3	3.0	2.7	0.1
1	0.0	56.6	28.6	1.1	3.3	0.1	0.1	0.1	8.3	0.1	0.1	1.5	0.1

Link 1 and link 3 are the two origin links, where vehicles enter the simulation. Link 1 represents the left lane of eastbound I-40 and link 3 is the right lane. These lines in the input file specify the percentage of each vehicle class to enter the simulation on each link. The percentage of each class was taken from the data collected by Crittendon County WIM site in May 1998. Mitretek used the proportions of traffic in each lane from 10 a.m. to 11 a.m., consistent with the peak truck traffic times described previously. Figure 5-3 shows the percentage of each vehicle class. When links 1 and 3 are defined in the “LinkInfo” section, the percentage of total traffic entering the simulation on each of the two lanes is defined.



**Figure 5-3. Distribution of Vehicle Classifications by Lane on Eastbound I-40**

#### [Attributes]

Each attribute (also called a characteristic) of a vehicle is determined at the time it enters the simulation. Some attributes are given other values during the simulation as a result of a test. The probability of each characteristic being set to true is specified. The probability may depend on the value of previously set attributes. The cab and/or trailer of a vehicle may be displayed in a certain color to indicate that a certain attribute is true. Attributes need not be defined in numerical order, and there may be gaps in the sequence of attribute numbers.

#	name	cab color	trailer color	%	expr	%	expr
#	----	-----	-----	---	-----	---	-----

1	"car"	yellow	yellow	100	{ c2 }		
---	-------	--------	--------	-----	--------	--	--

Cars are displayed in yellow. 100% of the vehicles in class 2 are designated as cars.

2	"truck"	default	default	100	{ ( not c2 ) and ( not c3 ) and ( not c4 ) }		
---	---------	---------	---------	-----	--	--	--

Trucks are normally displayed with the default color (blue). If the vehicle is not class 2, class 3, or class 4, there is a 100% chance that the vehicle will be a truck (i.e. all vehicles that are not cars, pickup trucks, or buses are trucks). Pickup trucks (class 3) and buses (class 4) are not treated like trucks since they are not required to stop for inspection.

3	"overweight"	default	lightred	owt	{ }		
---	--------------	---------	----------	-----	-----	--	--

This attribute is true if the vehicle is over gross weight (over 80,000 pounds). The special keyword "owt" indicates that this attribute is set by comparing the weight to the limit, rather than by drawing a new random value. Overweight trucks are displayed on the computer screen with red trailers.

According to data recorded by the Crittenden County WIM station, approximately 9 percent of the trucks are over 80,000 pounds gross weight (not counting class 3 pickup trucks).

4	"over axle weight"	default	default	94	{ 3 }	22	{ 2 and ( not 3 ) }
---	--------------------	---------	---------	----	-------	----	---------------------

Analysis of the 8,192 trucks recorded by the Crittenden Country WIM station revealed that 94 percent of trucks that were over 80,000 pounds gross weight also exceeded the maximum axle weight for one or more axles. The maximum axle weight is 20,000 pounds for any axle, and 12,000 pounds for the steering axle. Thus the model selects 94 percent of the trucks with attribute 3 (overweight) to be over axle weight as well. The same analysis revealed that 22 percent of the trucks under 80,000 pounds gross weight exceeded the maximum axle weight for one or more axles. Thus the model selects 22 percent of the trucks (attribute 2) that are not overweight (not attribute 3) to be over axle weight. In all approximately 29% of class 5 though class 13 trucks exceed maximum axle weight.

5	"weighed"	default	default	0	{ 2 }		
---	-----------	---------	---------	---	-------	--	--

Initially all vehicles have this attribute set to false. However, the trucks that are weighed at the static scale have this attribute set to true, so they can be counted and reported.

6	"safety check"	default	black	2	{ 2 }		
---	----------------	---------	-------	---	-------	--	--

If attribute 2 is true (the vehicle is a truck), there is a 2% chance the vehicle will be pulled over for a safety check. This percentage was the percentage of trucks pulled over for safety reasons as reported by SDDOT, since the corresponding data were not available from Arkansas. These trucks are displayed with black trailers.

7	"credential check"	lightred	default	4	{ 2 }		
---	--------------------	----------	---------	---	-------	--	--

If attribute 2 is true (the vehicle is a truck), there is a 4% chance the vehicle will be checked for credentials or logbook violations. This percentage was the percentage of trucks pulled over for credential checks as reported by SDDOT, since the corresponding data were not available from Arkansas. Trucks suspected of credentials or logbook problems are displayed with red cabs (suggesting that the problem is with the driver, not the cargo).

9	"fixable"	default	default	100	{ 3 }	100	{ 5 }	90	{ 4 }
---	-----------	---------	---------	-----	-------	-----	-------	----	-------



100% of the trucks with weight (attribute 3) or credential problems (attribute 5) are considered “fixable” in that they are allowed back on the highway after a short time. 90% of the trucks with safety problems (attribute 4) are allowed to leave after the problem is fixed or noted. However, 10% of the unsafe trucks are placed out of service for the remainder of the simulation. These percentages come from data recorded at the McCook, South Dakota station over two days in June, where one unsafe truck was effectively placed out of service each day out of 9 or 10 unsafe trucks.

10 "OOS"                      black              black              0 { }

Initially all vehicles have this attribute set to false. However, the trucks that are not fixable (10% of the unsafe trucks) are placed “out of service” and have this attribute set to true after inspection. They are displayed as all black, and they never leave the parking lot.

11 "bypass lane"              default              default              0 { }

Initially all vehicles have this attribute set to false. However, the trucks that traverse the bypass lane in the station have this attribute set to true, so they can be counted and reported.

12 "spilled in station" default              default              0 { }

This attribute is initially set to zero for all trucks. It is set to 1 if the truck is waved past the scales when the scales are temporarily shut down (see test 7).

13 "skipped station"              default              default              0 { }

Initially all vehicles have this attribute set to false. However, the trucks that remain on the highway mainline, skipping the station altogether, have this attribute set to true, so they can be counted and reported.

14 "inspected"              default              default              0 { }

Initially all vehicles have this attribute set to false. However, the vehicles that have been pulled into the parking lot and then released have this attribute set to true, so they will not be counted as bad misses by test 10 or test 11.

15 "missed overwt"              black              default              0 { }

This attribute is set to true when a truck that is overweight leaves the simulation without having been inspected (see test 10). It is defined so that the model can report the number of such trucks. The cabs of these trucks are displayed black.

16 "missed cred/safe"              black              default              0 { }

This attribute is set to true when a truck that has safety or credential problems leaves the simulation without having been inspected (see test 11). It is defined so that the model can report the number of such trucks. The cabs of these trucks are displayed white.

17 "random"                      default              default              50 { 2 }

Fifty percent of the trucks have this attribute set true. This attribute is use in two different ways. First, half the trucks that remain on the highway (either because they have transponders or because there is overflow), switch to the left lane to make room for trucks merging out of the station. Second, half of the overweight trucks, or trucks with safety or credential problems that are in the bypass lane within the station get stopped and pulled over into the parking lot. Tests 12 and 13 check for this attribute, with the result that half the trucks are selected.

18 "transponder"              lightgreen default              12 { 2 }

In the base case, 12 percent of the trucks have transponders. These trucks may bypass the weigh station without stopping. This policy is different for the configurations with mainline WIM scale. The percentage of trucks with transponders is varied as a study parameter. A truck with a transponder may be overweight or may have safety or credentials problems.

#### [Tests]

Each branch and parking lot link performs a test on each vehicle as it enters the link. The test is a Boolean combination of vehicle attributes. If the value of the test is true, the vehicle leaves the branch link by the alternate link (the second link named in the link file). If the value of the test is false, the vehicle leaves the branch by the main link (the first link named in the link file). More than one branch may perform the same test. If an attribute number is specified in the second part of the test, that attribute is set to true for all vehicles that pass the test.

1 "trucks to right lane" A { 2 } { }

All trucks (not including pickup trucks) take the alternate branch to the right. This test is used to move any trucks still in the left lane when the station is at hand (link 6) to the right lane (link 9)

2 "transponder check" A { 2 and ( not 18 ) } { }

This test is used to direct all trucks that do not have a transponder onto the station entrance ramp (link 21). All other vehicles (trucks with transponders and vehicles other than class 5-13 trucks), remain on the mainline.

3 "to scales" A { 4 } { }

This test represents the operation of the WIM scale. All trucks that are over maximum axle weight (attribute 4) take the alternate branch toward the static scale. All other trucks take the bypass lane back to the highway. This test is applied by link 21 (the station entrance ramp).

4 "to parking lot" A { 3 or 6 or 7 } { }

All trucks that are overweight (attribute 3) or unsafe (attribute 6) or have credentials problems (attribute 7) take the alternate branch from the scales toward the parking lot. All other trucks take the primary branch back to the highway. This test is applied by link 33 (the scale link). It represents the decision of the station operator.

5 "safety check" A { not 9 } { 10 }

This test is performed in the parking lot (link 36). All vehicles that are not fixable (not attribute 9) are tagged with attribute 10 (out of service). Those trucks will not leave the parking lot. Otherwise, after waiting the appropriate length of time, they return to the highway.

6 "tag bypasses" A { 2 } { 11 }

The bypass lane (link 22) applies this test to all trucks traversing it. Since the test only checks whether it is a truck (attribute 2), no trucks fail this test. In fact, both exit links are the same. The only purpose of this test is to set attribute 11 (bypassed) to true for those trucks, so they can be counted and reported.

7 "tag spills" A { 2 } { 12 }

Links 33 and 39 are defined as occupying the same physical space. Link 33 contains a static scale and link 39 does not. When the scales are closed because of queue backup, link 33 closes, and trucks are switched to link 39. Thus the only time a truck traverses link 39 is when the scales are closed.

Therefore all trucks on link 39 have attribute 12 (spilled in station) set to true so they can be counted and reported.

8 "tag skipped station" A { 2 } { 13 }

The mainline link adjacent to the station (link 11) applies this test to all trucks traversing it. Since the test only checks whether it is a truck (attribute 2), no trucks fail this test. In fact, both exit links are the same. The only purpose of this test is to set attribute 13 (skipped station) to true for those trucks, so they can be counted and reported.

9 "tag inspected" A { 2 } { 14 }

The link exiting the parking lot (link 37) applies this test to all trucks traversing it. The purpose of this test is to set attribute 14 (inspected) to true for those trucks, so they can be counted and reported, and so that the model can check whether overweight trucks have been caught.

10 "tag overwt misses" A { 3 and ( not 14 ) } { 15 }

This test sets attribute 15 (missed overwt) to true whenever an overweight truck (attribute 3) is past the station on link 14 or 19 and has not been inspected (attribute 14 is still false). These are the trucks that should have been cited but were not.

11 "tag miss safe/cred" A { ( 6 or 7 ) and ( not 14 ) } { 16 }

This test sets attribute 16 (missed cred/safe) to true whenever a truck with safety problems (attribute 6) or credential problems (attribute 7) is past the station on link 15 or 18 and has not been inspected (attribute 14 is still false). These are the trucks that should have been inspected but were not.

12 "catch some bypass" A { 17 and ( 3 or 6 or 7 ) } { }

Trucks with safety problems (attribute 6) or credential problems (attribute 7) may take the bypass lane within the station because they are not over axle weight, and trucks overweight (attribute 3) may take the bypass lane if the line to the static scale is full. There is a fifty percent chance that these trucks will be spotted on the bypass lane by the station operator, stopped, and required to proceed to the parking lot. This test is true if any of these attributes are true and the random attribute (fifty percent of trucks) is true.

13 "bypassers left" A { 17 } { }

This test is performed on the mainline link 12 passing the station. Half the trucks bypassing the station for any reason switch to the left lane (link 18).

14 "tag weighed" A { 2 } { 5 }

This test is performed on the branch 32 leading to the static scale. All trucks on this link will be weighed at the scale, so the weighed attributed (attribute 5) is set to true.

[ServiceTimes]Service times are specified for scales and branches as probability distributions. Different distributions may be specified for different Boolean combinations of vehicle classes. The types of possible distributions are Normal, Uniform, Erlang, or Constant.

#	name	expression	random type	parms#
1	"weighing time"	{ } Erlang	47	

The service time distribution was calculated from data recorded at the Lehi station June 18, 1998. In all there were 488 observations recording the time each a truck stopped on the eastbound or

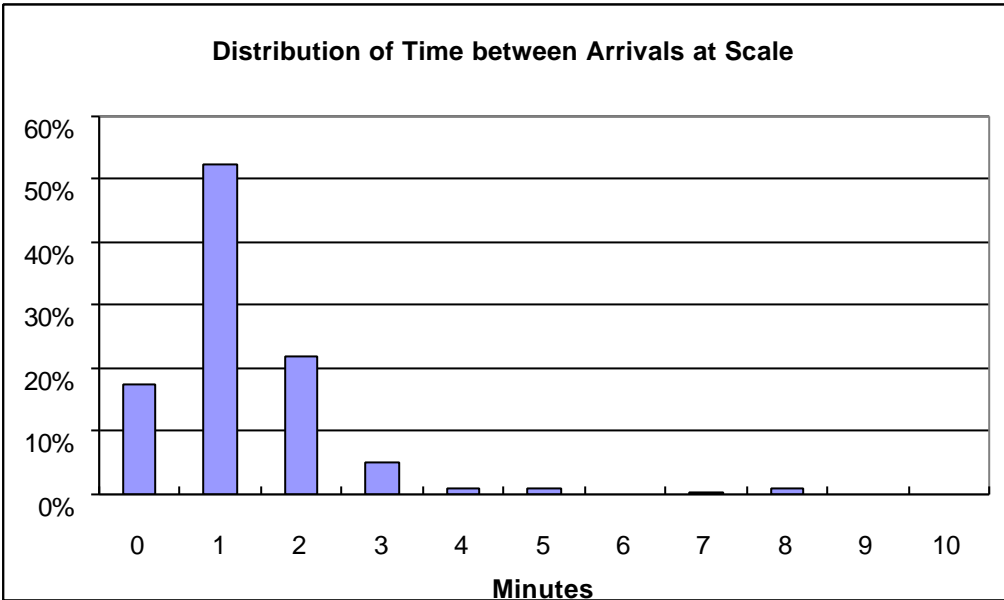
westbound scales. The distribution of the times between truck arrivals on the scales is shown in figure 5-4. The plot suggests that the distribution of service times is consistent with an Erlang distribution (see figure 2-6). The data were recorded only to the nearest minute. Mitretek determined that an average service time of 63 seconds best matched the observed arrivals in minutes. The average service time of 63 seconds is composed of an average of 47 seconds to weigh the truck and 17 seconds between the time one trucks begins to pull away from the scales and the next truck pulls up onto the scales and stops.

2 "inspection time" { 3 } Erlang 600 { 6 } Erlang 1500 { 7 } Erlang 300 # seconds

Mitretek has estimated an average time of 10 minutes to give a citation to an overweight truck (attribute 3), 25 minutes to perform a truck safety inspection (attribute 6) and 5 minutes to check driver credentials or logbooks (attribute 7). These times are estimates since actual data from Arkansas were not available. The assumption of an Erlang distribution of service times is compatible with Mitretek's experience for South Dakota, where individual inspection times were recorded.

3 "stop on bypass lane" { } Constant 15

Half of the overweight trucks, or trucks with safety or credential problems that are in the bypass lane within the station get stopped and pulled over into the parking lot. Those that are stopped at this point remain stopped for 15 seconds before pulling into the parking lot.



**Figure 5-4. Distribution of Time between Trucks on Scale at Lehi**

**[LinkInfo]**

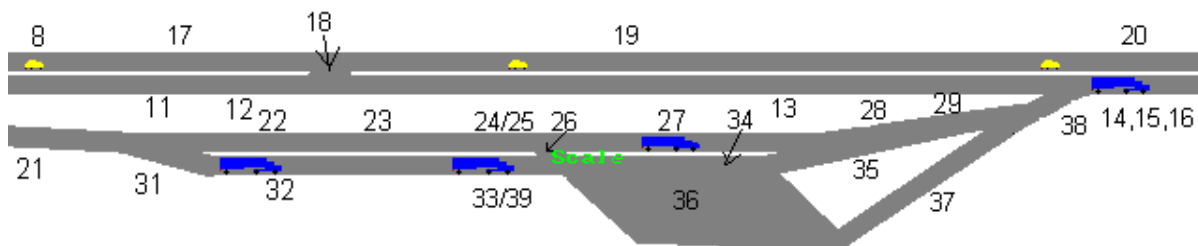
This section specifies information for each link in the simulation. The first column is the link number. The second column gives the type of link. The third and fourth columns specify the first and second links following the given link. Two exit links are specified only if the link is a branch or scale; otherwise there is a dash (-). The fifth column specifies the free speed limit in miles per hour. The sixth and seventh columns specify the x and y coordinates (in feet) of the start of the link and the

eighth and ninth columns specify the x and y coordinates of the end of link. Mitretek determined the link coordinates from a scale drawing of the Lehi facility provided by AHTD.

Notes on individual links follow the listing. Figure 5-5 provides an overview of the station as modeled in Westa, showing link numbers. Figure 5-6 presents a close-up of the central weighing and inspection area. Table 5-4 presents the special characters used to specify link options in the LinkInfo section. Table 5-5 presents the LinkInfo section of the base case input file.



**Figure 5-5. Overview of Lehi Station on Eastbound I-40**



**Figure 5-6. Detail of Central Area of Lehi Station**

<b>Code</b>	<b>Explanation</b>
T	Precedes the test number for a branch link
ST	Precedes the service time number for a branch or scale link
Y	Indicates that traffic on that link must yield when merging with traffic from another link
CC	Precedes the coordinates of the center of curvature for a curved link
PS	Precedes the number of parking spaces for a parking lot
OC	Precedes the x and y coordinates of the opposite corner of a parking lot (the corner directly opposite the corner where trucks enter the lot)
NQ	Specifies that no queuing applies in the parking lot (service time starts as soon as the truck parks, rather than waiting for any other trucks in the lot)
A	Indicates the proportion of arrivals to appear on each origin link
AS	Exit from the link is governed by an actual signal keyed on the designated link
CL	The link is closed when the designated link reaches the closing threshold (see “C” ) and reopens when the designated link reaches the reopening threshold (see “O”)
C	The link closes when the ratio of total truck length to total link length exceeds this fraction
O	The link reopens when the ratio of total truck length to total link length drops below this fraction
LL	Indicates the link number of the corresponding left-hand lane where lane-changing is permitted
RL	Indicates the link number of the corresponding right-hand lane where lane-changing is permitted
Q	The number of trucks in this link is to be included in the queue length count
SC	Indicates that when this link is closed, the station is closed (the simulation keeps track of how long the station is closed).

**Table 5-4. Special Link Options in the LinkInfo Section**

#	Type	Next	Spd	x1	y1	x2	y2	Special codes
1	Orig	2 -	55	3370	315	3580	315	RL 3 A .35
2	Trans	6 -	55	3580	315	3995	315	RL 4
3	Orig	4 -	55	3370	300	3580	300	LL 1 A .65
4	Trans	7 -	55	3580	300	3995	300	LL 2
6	Branch	8 9	55	3995	315	4370	315	RL 7 T 1
7	Trans	10 -	55	3995	300	4415	300	LL 6
8	Trans	17 -	55	4370	315	4830	315	
9	Trans	10 -	55	4370	315	4415	300	Y
10	Branch	11 21	55	4415	300	4830	300	T 2 LL 8
11	Branch	12 12	55	4830	300	5900	300	LL 17 T 8
12	Branch	13 18	55	5900	300	6500	300	T 13
13	Trans	14 -	55	6500	300	7565	300	
14	Branch	15 15	55	7565	300	7665	300	T 10
15	Branch	16 16	55	7665	300	7770	300	T 11
16	Dest	- -	55	7770	300	7850	300	
17	Trans	19 -	55	4830	315	6545	315	
18	Branch	19 19	55	6500	300	6545	315	Y T 11
19	Branch	20 20	55	6545	315	7565	315	T 10
20	Dest	- -	55	7565	315	7850	315	
21	Branch	22 31	20	4830	300	6190	240	T 3 Q SC C .6 O .2
22	Branch	23 23	15	6190	240	6700	240	T 6
23	Branch	24 25	15	6700	240	6800	240	T 12
24	Trans	27 -	15	6800	240	6845	240	
25	Branch	27 26	15	6800	240	6845	240	T 12 ST 3 CL 21 C .6 O .2
26	Trans	36 -	15	6845	240	6885	215	
27	Trans	28 28	15	6845	240	7180	240	
28	Trans	29 -	30	7180	240	7335	280	
29	Trans	38 -	40	7335	280	7480	290	
30	Trans	36 -	10	6865	225	6885	215	
31	Trans	32 -	10	6190	240	6295	225	CL 32 C .65 O .6 Q
32	Branch	39 33	10	6295	225	6845	225	Q T 2
33	Branch	34 30	10	6845	225	6865	225	ST 1 T 4 CL 21 C .6 O .2
34	Trans	35 -	15	6865	225	7150	225	
35	Trans	42 -	30	7150	225	7215	245	
42	Trans	29 -	30	7215	245	7335	280	Y
36	Park	37 37	5	6885	215	7210	150	OC 6970 150 ST 2 T 5 PS 14 NQ
37	Branch	38 38	30	7210	150	7480	290	Y T 9
38	Trans	14 -	50	7480	290	7565	300	Y
39	Branch	34 34	10	6845	225	6865	225	T 7
40	Bldg	- -	0	6795	180	6830	210	"Office"
41	Bldg	- -	0	6780	220	6850	230	"Scale"

**Table 5-5. Base Scenario LinkInfo Section**

Links 1, 2, 6, 8, 17, 19, and 20 are the left lane of Eastbound I-40. Link 1 is the origin link, delivering 35 percent of the vehicles. Any trucks on links 1, 3, or 6 may shift right to link 3, 4, and 7 respectively if there is sufficient room. Cars may switch lanes at will, given a sufficient gap, but trucks may only shift to the right lane from the left lane.

All trucks that haven't shifted to the right lane by the end of link 6 must take the branch (link 9), which merges with link 7 into link 10 (changes from the left lane to the right lane). Traffic on link 9 yields to

traffic on link 7. Cars, buses, and pickup trucks on link 6 continue on to links 8, 17, and 19, bypassing the weigh station. Any overweight vehicles on link 19 that haven't been inspected are tagged as missed overweight trucks (attribute 15). Vehicles completing destination link 20 exit the simulation.

Links 3, 4, 7, 10, 11, 12, 13, 14, 15, and 16 are the right lane of eastbound I-40. Link 3 is the origin link, delivering 65 percent of the vehicles. Cars, buses, and pickup trucks on links 3, 4, 7, 8, and 10 may change lanes to the left onto links 1, 2, 6, 8, and 17 respectively if there is enough space. Link 10 is the branch link in the right lane. At the end of this branch, all trucks except those with transponders must exit the highway into the station on the ramp link 21. Cars and pickup trucks continue on highway link 11.

Any trucks on link 11 are tagged as skipping the station (attribute 13). Any truck that is skipping the station on branch link 12 has a 50% probability (attribute 17) of taking link 18, switching to the left lane (ordinarily trucks do not have the option of switching lanes to the left).

Any overweight trucks on link 14 that haven't been inspected are tagged as missed overweight trucks (attribute 15). Any trucks on link 15 with safety or credential problems that haven't been inspected are tagged as missed safety/credentials trucks (attribute 16). Vehicles completing destination link 16 exit the simulation.

Link 21 is the ramp into the station. It also contains a low-speed WIM scale. Trucks with an axle weight violation (attribute 4) are directed onto link 31 toward the static scales. Other trucks are directed to link 22, the bypass lane. When trucks occupy more than 60 percent of the link (the sum of the lengths of trucks on the link is greater than 60 percent of the link length), the link closes. In the simulation graphics, a closed link is shown in yellow. When this link is closed, the station is closed, and all trucks remain on the mainline. The link does not reopen until trucks take up less than 20 percent of the link length. Whenever the station closes or reopens, a message is written to the summary output file.

Link 31 leads from the WIM scale on link 21 toward the static scale. It may close depending on how full is link 32 (the queue to the static scale). When link 32 is more than 65% full, link 31 closes. When link 31 is closed, branch link 21 does not send any trucks to it; instead all trucks must take link 22 (the bypass lane). When the total length of trucks on link 32 drops below 60% of its length, link 31 reopens.

Link 32 is the queue for the static scale (link 33). It too, is a branch. If the static scale is closed (see next paragraph) all trucks are routed instead to link 39. Link 39 physically occupies the same space as link 33, but a stop is not required. In other words, when the scales are closed and trucks are waved by without stopping, they are modeled as traveling on link 39 rather than link 33. All trucks set to the static scale (link 33) by this link have attribute 5 (weighed) set to true.

Link 33 is the static scale where test 4 is applied (is the truck overweight or is there a reason for a safety or credential check?) If any of these are true, the truck takes the right branch (link 30) to the parking lot. If no further check is required, the truck takes the left branch (link 34) toward the station exit. Service time 1 defines how long it takes to weigh a truck on the scales after it has stopped. The scales are closed if the station entrance backs up too far. Specifically, when link 21 is more than 60% full, link 33 closes. When link 33 is closed, branch link 32 does not send any trucks to it; instead all trucks must take link 39. Link 39 occupies the same space as link 33, but trucks are not required to stop.



Link 22 is the beginning of the bypass lane within the station. All trucks traversing this link have attribute 11 set to true by test 6. Link 23 is the continuation of the bypass lane. It too, is a branch. If a truck passes test 12 (it is overweight or has credentials or safety problems and is one of the 50% of such trucks that are stopped), it is sent to link 25, where it must stop. Otherwise, or if link 25 is closed, it is sent to link 24, on its way out of the station.

On link 25 trucks that pass test 12 described above must stop for 15 seconds, then take link 26 to the parking lot. Link 25 closes if the backup on the station entrance ramp (link 21) is too great. When link 25 closes, all trucks pass from link 24 to link 27. Link 27 occupies the same space as link 25, but trucks are not required to stop and may not get sent to the parking lot. If link 25 is closed, it will reopen when the length of trucks on link 21 drops to less than 20% of its length.

The definitions for links 21, 31, 32 include a "Q". This tells the model to sum the number of trucks on these three links to compute the current queue length.

Links 27, 28, 29, 30, 34, 35, 38, and 42 lead away from the scales and the bypass lane to rejoin the highway. Trucks on link 38 must yield to highway traffic on link 13, as both links merge onto link 14.

The static scale (link 33) and the link from the bypass lane (link 26) lead to the parking lot (link 36). In the parking lot, test 2 (safety inspection) is applied. Service time 2 defines the distribution of times to perform a safety, credential, or weight distribution inspection and to fix the problem. If the truck is fixable, after waiting the appropriate time, it exits the lot on the parking lot exit ramp (link 37). All trucks on link 37 leaving the parking lot have their attribute 14 (inspected) set to true.

Links 40 and 41 are not links at all, but are simply labeled locations shown on the display. Link 40 is the office and link 41 is the scale.

#### [GraphInfo]

The following lines define the statistics boxes in the lower left corner of the screen. The first six statistics display the current cumulative count of vehicles with certain attributes. A vehicle does not get counted in these statistics until it leaves the simulation, either by exiting a destination link or by being placed out of service in the parking lot. The last statistic gives the total number of trucks in links defined with a "Q" (i.e. links 21, 31, and 32).

```
Stat  "Total number of trucks" Count 2
Stat  "Number trucks bypassed" Count 11
Stat  "Skipped station"         " Count 13
Stat  "Spilled past scales"     " Count 12
Stat  "Overweight trucks"       " Count 3
Stat  "Overweights missed"      " Count 15
Stat  "Current queue length"    Queue
```

The following lines define six "views". These are preset coordinates that can be invoked by pressing a single number key during the simulation. View 1 shows the highway lanes approaching the station, where all trucks in the left lane must shift to the right. View 2 shows the station ramp. View 3 shows the bypass lane in the station and the queue for the static scale. View 4 shows the scales and parking

lot. View 5 shows the links where trucks leave the station to reenter the highway. View 6 shows a close-up of the area around the static scales.

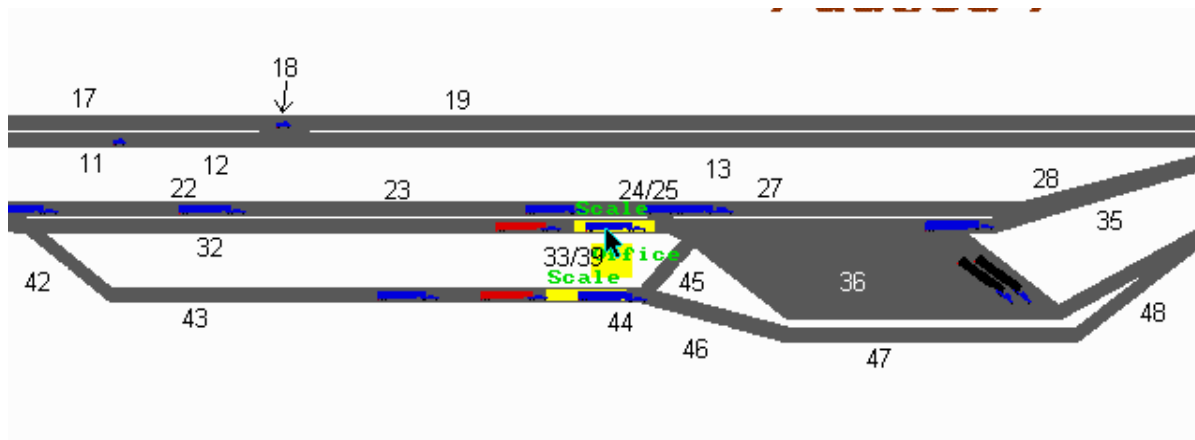
```

View 1  4311  4976   -17   482
View 2  4960  6000  -157   622
View 3  5688  6988  -255   720
View 4  6721  7387   -17   482
View 5  6988  7653   -17   482
View 6  6707  7047   105   360
[End]

```

### 5.3 First Alternate Configuration

At the request of AHTD, Mitretek modeled the operation of a proposed enhancement to the Lehi station, in which there are two static scales, one on either side of the office. The station layout is the same as the existing layout, except that trucks sent by the low-speed WIM scale to the static scale have the choice between the two static scales. In the model, trucks choose the scale with the shortest queue. Figure 5-7 shows how Westa represents the different configuration.



**Figure 5-7. Proposed Weigh Station with Dual Static Scales**

The first alternate configuration was modeled with the following changes in the input file. First, new links were defined for the static scale and links to and from the static scale.

42 Trans	43 -	10	6295	225	6370	165	Q
43 Branch	44 44	10	6370	165	6820	165	Q T 14
44 Branch	46 45	10	6820	165	6840	165	ST 1 T 4
45 Trans	36 -	10	6840	165	6885	215	
46 Trans	47 -	20	6840	165	6970	130	
47 Trans	48 -	20	6970	130	7225	130	
48 Trans	49 -	20	7225	130	7350	225	
49 Trans	38 -	20	7350	225	7480	290	

Links 42 and 43 lead to the new static scale to the right of the office. They are counted as part of the queue for the static scales. Link 43 is a branch, applying test 14, which tags any trucks crossing it as being weighed. Link 44 is the static scale, with the same service time and test number as the original

static scale. Link 45 leads from the new scale to the parking lot. Links 46 through 49 lead around the parking lot and back to the highway, merging with the existing reentry ramps.

Next, a new test was defined to for trucks to decide between the left and right scale depending on which has the shorter queue.

```
15 "Queue check"          A { Q 43 < Q 32 } { }
```

Next link 31 was changed from a transit link to a branch link, where test 15 is applied.

```
31 Branch                32 42    10    6190    240 6295    225    CL 32 C .65 O .6 Q T 15
```

Link 31 continues to close if the backup to the static scale on link 32 becomes too great.

## 5.4 Second Alternate Configuration

The second alternate configuration is the addition of a mainline WIM scale to the base configuration. Its use is coupled with the use of transponders by trucks. If a truck with a transponder does not exceed the maximum axle weight as measured by the mainline WIM scale, that truck is permitted to bypass the station. Permission to bypass the station is conveyed by a green light on the transponder unit in the truck cab. All trucks without transponders and all trucks exceeding maximum axle weight must enter the station. There may be trucks with transponders that exceed maximum axle weight, and therefore must enter the station.

There is no figure for this configuration, because the station layout looks the same as for the base case. There are only two differences in the input file. The first is test 2 is changed from simply checking for a transponder to a two-part test. Now the test specifies that trucks (attribute 2) that are over axle weight (attribute 4) or do not have a transponder (attribute 18) must enter the station. A truck with a transponder this is over axle weight must enter the station.

```
2 "Mainline WIM"         A { 2 and ( 4 or ( not 18 ) ) } { }
```

The test on link 10 uses the newly defined test 14

```
10 Branch                21 11    55    4415    300 4830    300    T 2 LL 8
```

## 5.5 Combined Changes Configurations

Alternate configuration three combines the changes from alternate configurations one and two. In other words, there are dual static scales and a mainline WIM scale. There is no figure for this configuration because it looks like alternate configuration one with the dual scales. The changes for both alternate configurations described in sections 5.3 and 5.4 are both found in the input file for the third alternate configuration.

## 5.6 Alternate Transponder Percentage Scenarios

In current operations at the Lehi station, 12 percent of the trucks have transponders. To model the effect of expected growth in use of transponders, Mitretek ran each of the four configurations with four different percentages of trucks having transponders. Specifically, configurations were run with 12%, 20%, 30%, and 40% of the trucks having transponders. Each combination of a configuration and

a transponder percentage is called a scenario. In the scenarios using the base case and first alternate configurations, all trucks with transponders could bypass the station. In the scenarios using the second and third alternate configurations, only trucks with transponders that were also under maximum axle weight could bypass the station.

## Section 6

# Results for Seymour Weigh Station

### 6.1 Results for Base Traffic Load Scenarios

Mitretek ran ten iterations for each of the ten scenarios using different random seeds for each iteration. Each iteration produced a summary file, from which the following values were extracted:

- ◆ Total number of trucks
- ◆ Total number of overweight trucks
- ◆ Total number of trucks to bypass the station when it was closed
- ◆ Total number of overweight trucks to bypass the station when it was closed
- ◆ Average time to transit the station spent by legal weight trucks that entered the station
- ◆ Average queue length for the static scale
- ◆ Total time during the simulation that the station was closed because of queue overflow
- ◆ Total seconds of hard deceleration (greater than 0.2g) for trucks on the entrance ramp
- ◆ Total seconds of hard deceleration for cars and trucks ( $> .2g$  for trucks,  $> .3g$  for cars) on the mainline approaching the spot where trucks exiting the station merge onto the highway.

The results are presented and plotted for each scenario. For each measure of effectiveness, a table presents the average value  $\Sigma x_i/10$ , the standard deviation  $\sqrt{(\Sigma x_i^2/10)}$  and the statistical significance coming from a  $\chi^2$  (chi-square) test comparing the results for each iteration of an alternate scenario against the ten iterations of the base scenario. If the level of significance is greater than 90% or 95%, there is high confidence that the alternate scenario does indeed make a significant difference to the average value of the measure of effectiveness. If the level of significance is less than 90%, it cannot be said that the alternative scenario has a different result than the base scenario.

Following each table, a plot shows the average value across the 10 iterations for each scenario. The average for the base case scenario is a black square, the averages for the two longer ramp scenarios are blue squares, the averages for the six transponder scenarios are green squares, and the average of the WIM scale scenario is a red square. Each plot also features vertical bars indicating one standard deviation above and below the average for each scenario. If the standard deviation is large in relation to the difference between the average value for the base scenario and the average value for the alternate scenario, then the difference in the average value is not likely to be statistically significant. In general, the smaller the standard deviation, the more likely results are to have high values of statistical significance.

#### 6.1.1 Average Station Closed Time

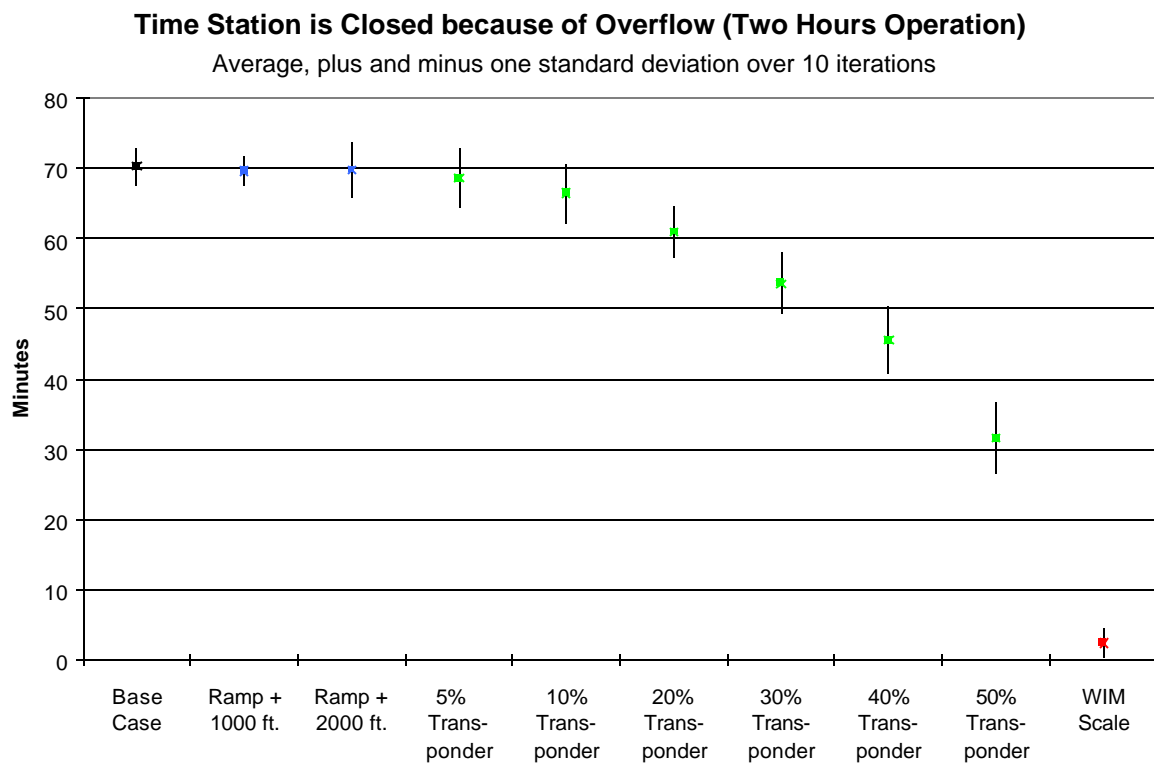
Table 6-1 and figure 6-1 present the average time (in minutes) the station was closed because of queue overflow. The amount of time represented by the simulation was two hours. Most of the scenarios resulted in the station being closed over half the time.

The key input values driving this result were the arrival rate of trucks and the average time to weigh a truck. Mitretek observed the Seymour station operation during the morning hours in March 1998, when the arrival rate of trucks was less than the peak arrival rate modeled here. Nevertheless, the station closed at least eight times during the three hours observed. Thus the results obtained from the

base scenario seem reasonable. Indiana officials concurred that the results are consistent with their experience.

	Base Case	Ramp +1000 feet	Ramp + 2000 feet	5% Transponder	10% Transponder	20% Transponder	30% Transponder	40% Transponder	50% Transponder	WIM Scale
Mean	70.3	69.6	69.8	68.6	66.4	61.0	53.6	45.5	31.6	2.4
Std. Deviation	2.69	2.17	4.00	4.19	4.26	3.71	4.46	4.85	5.21	2.05
Statistical Significance		46%	25%	70%	97%	100%	100%	100%	100%	100%
Difference is Significant?		No	No	No	Yes	Yes	Yes	Yes	Yes	Yes

**Table 6-1. Statistics for the Number of Minutes the Station is Closed**



**Figure 6-1. Average Time Station is Closed**

In the scenario with longer ramps, the ramps held more trucks before they filled up, but once that point was reached there was no difference in operation. Because of the policy for keeping the entire ramp closed until it emptied out, each time the station closed it remained closed for a long time. The longer closing times balanced out the longer times the station was open between closings.

The scenario with 5% transponder barely made a difference in the number of station closings. As the percentage of transponders increased, the number of trucks required to enter the station and be weighed decreased, with corresponding reduction in the amount of queue overflow. At the 50% level, the time the station was closed was half that of the base level.

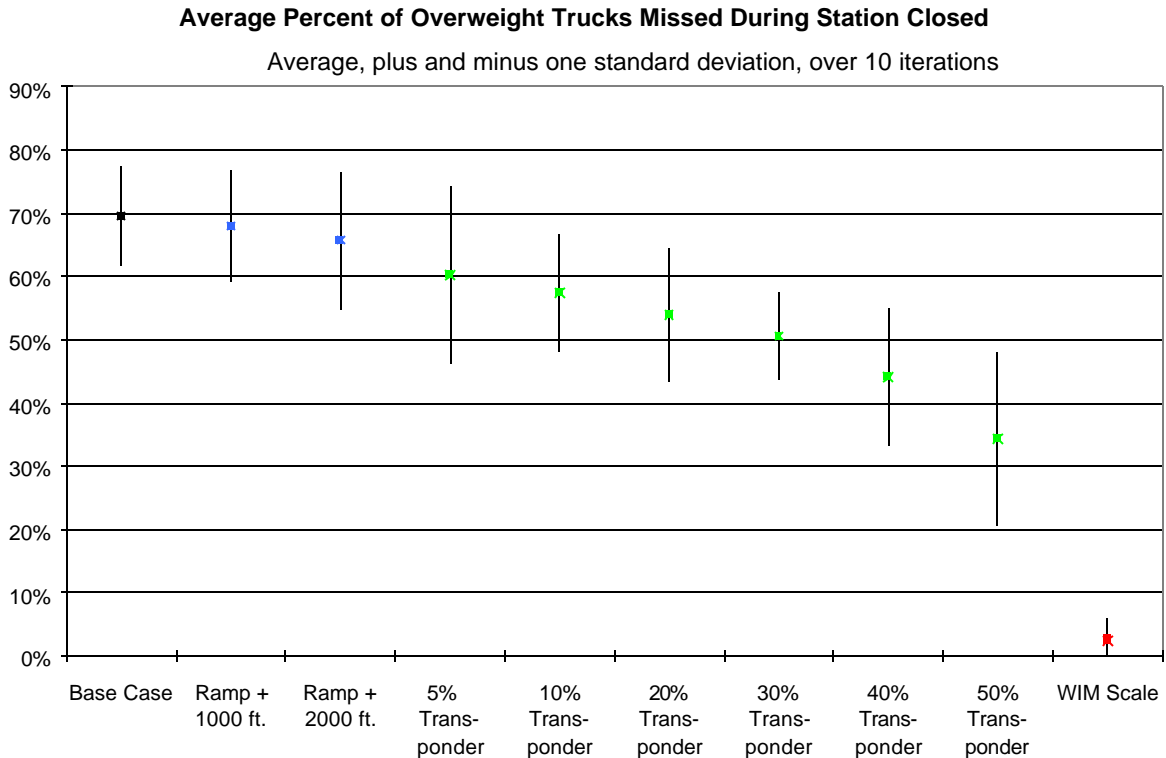
The WIM scale effectively removed over 70% of the trucks from the static scales, so there was no backup of trucks waiting to be weighed. In other words, the arrival rate of trucks to be weighed was below the rate at which they could be weighed. Therefore the time the station was closed was reduced nearly to zero. It should be noted that if the queue of trucks waiting for the static scale backed up past the point where the bypass lane diverged from the entrance ramp, then underweight trucks were stuck in the queue as well. When that situation happened, the high arrival rate caused the queue to grow quickly until the diverge point to the bypass lane was clear for underweight trucks.

### 6.1.2 Average Percent of Overweight Trucks Missed Because of Station Closing

For each iteration, Mitretek computed the proportion of overweight trucks missed as the number of overweight trucks that bypassed the station when the station was closed divided by the total number of overweight trucks. For each scenario, Mitretek found the average percent of overweight trucks missed across the ten iterations. Table 6-2 and figure 6-2 present the results.

	Base Case	Ramp +1000 feet	Ramp + 2000 feet	5% Transponder	10% Transponder	20% Transponder	30% Transponder	40% Transponder	50% Transponder	WIM Scale
Mean	0.70	0.68	0.66	0.60	0.57	0.54	0.51	0.44	0.34	0.03
Std. Deviation	0.07	0.09	0.09	0.07	0.05	0.08	0.07	0.12	0.05	0.04
Statistical Significance		33%	62%	91%	99%	100%	100%	100%	100%	100%
Difference is Significant?		No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

**Table 6-2 Statistics for Percent of Overweight Trucks Missed**



**Figure 6-2. Average Percent of Overweight Trucks Missed**

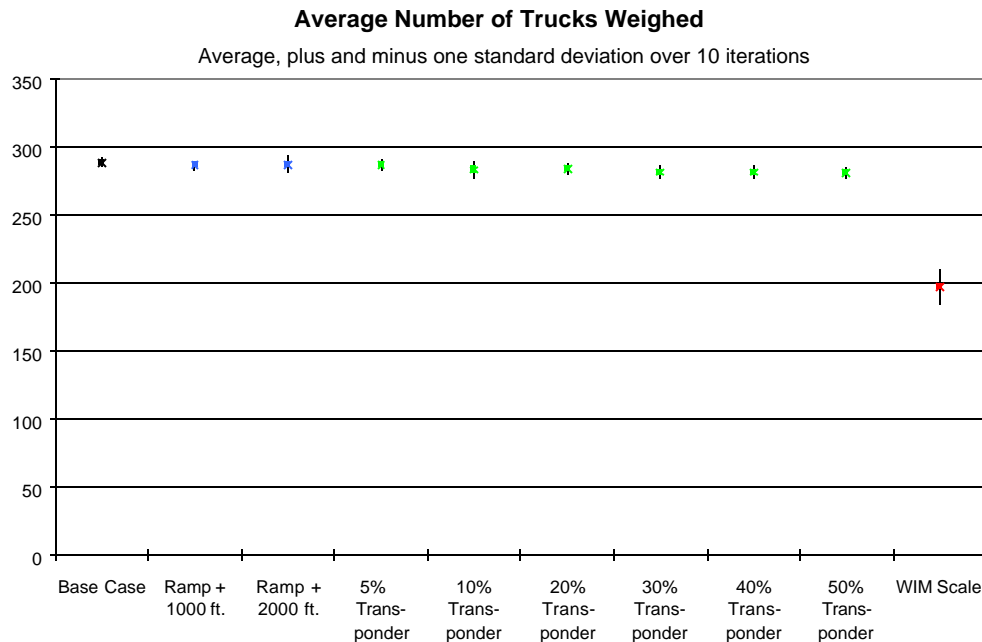
The results are roughly proportional to the amount of time the station was closed. That stands to reason, because overweight trucks are generated throughout the simulation, and the chance of an overweight truck approaching the station at a time when it is closed is proportional to the chance the station is closed. There is a slight reduction in this figure for the scenarios with longer ramps, but the reduction is not statistically significant. As the proportion of trucks with transponders increases, the station is closed less and a smaller proportion of overweight trucks are missed. Since the station was seldom closed with a WIM scale, very few overweight trucks were missed.

### 6.1.3 Average Number of Trucks Weighed

Table 6-3 and figure 6-3 show the average number of trucks weighed for each scenario. Except for the WIM scenario, this number is practically constant. The arrival rate of trucks was nearly always high enough to keep a supply of trucks waiting to be weighed. In other words, the scales were seldom idle during the simulated period. The number of trucks weighed during the two hour simulation was roughly equal to two hours divided by the average time to weigh a truck: 7200 seconds / 25 seconds = 288. The very small reductions for scenarios with higher transponder percentages were statistically significant only because the standard deviations were so small. Only for the WIM scenario, where the arrival rate of trucks at the static scale was well below a rate of one every 25 seconds, did the number of trucks weighed decrease substantially.

	Base Case	Ramp +1000 feet	Ramp + 2000 feet	5% Transponder	10% Transponder	20% Transponder	30% Transponder	40% Transponder	50% Transponder	WIM Scale
Mean	288.90	286.60	287.50	286.90	283.40	284.30	281.70	281.70	280.70	197.20
Std. Deviation	3.25	3.95	6.15	4.91	6.19	4.83	5.03	4.95	4.62	12.78
Statistical Significance		33%	47%	70%	98%	98%	100%	100%	100%	100%
Difference is Significant?		No	No	No	Yes	Yes	Yes	Yes	Yes	Yes

**Table 6-3. Statistics for Number of Trucks Weighed**





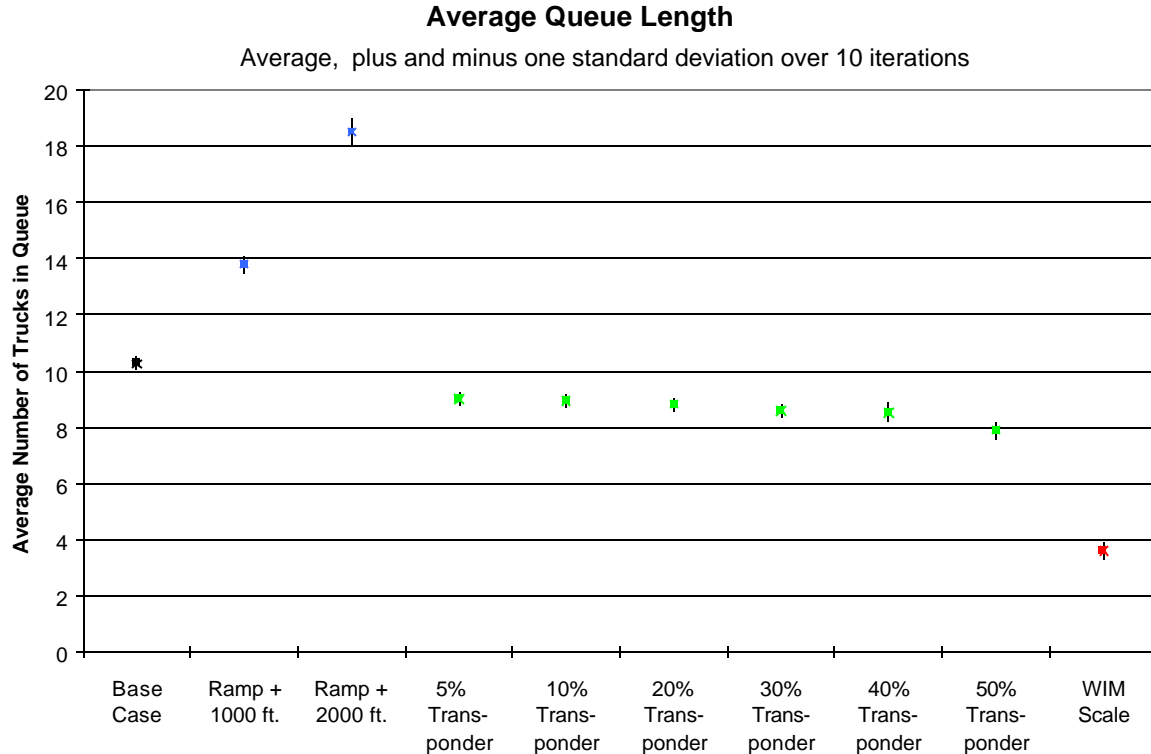
**Figure 6-3. Average Number of Trucks Weighed**

#### 6.1.4 Average Queue Length

Table 6-4 and figure 6-4 show the average queue length over the course of the simulated two hours. This statistic included the count of all trucks on links 21, 22, and 23 up to the static scale. During the simulation the queue cycled among the following states: (a) maximum value when trucks reach the entrance to the ramp on the highway, causing the station to close, (b) decreasing in size as trucks are processed through the scale and no new trucks are added, (c) minimum value as link 21 is empty (but trucks are still on links 22 and 23), causing the station to reopen, and (d) growing, as trucks leave the queue to be weighed, but trucks arrive from the highway at a faster rate than they can be weighed. Because of this cycling behavior, the average queue length is roughly the number of trucks that can fit on links 22 and 23 plus half the number of trucks that can fit on link 21. The number of trucks that fit on each link is not constant because of the variations in truck length, but it doesn't change much.

	Base Case	Ramp +1000 feet	Ramp + 2000 feet	5% Trans-ponder	10% Trans-ponder	20% Trans-ponder	30% Trans-ponder	40% Trans-ponder	50% Trans-ponder	WIM Scale
Mean	10.27	13.79	18.51	9.00	8.94	8.82	8.58	8.52	7.88	3.60
Std. Deviation	0.24	0.31	0.49	0.24	0.27	0.25	0.25	0.35	0.33	0.35
Statistical Significance		100%	100%	100%	100%	100%	100%	100%	100%	100%
Difference is Significant?		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

**Table 6-4. Statistics for Average Queue Length**



**Figure 6-4. Average Queue Length**

It is clear that the average queue length for the scenarios with longer ramps was greater than the average queue length for the base scenario and the transponder scenarios. The longer ramp is able to hold a longer queue and does so. For the scenarios with transponders, the reduction in average queue length was small, but statistically significant because of the small standard deviation. In other words, the transponder scenarios consistently had slightly shorter queues on average because the smaller arrival rate for trucks caused an occasional moment of slack in the queue. Only for the WIM scenario, where arrival rate was less than the service rate, was the queue size significantly shorter.

### 6.1.5 Average Time to Transit Station

Table 6-5 and figure 6-5 show the average time to transit the station for trucks of legal weight that entered the station. Trucks that bypassed the station because of having a transponder or because the station was closed are excluded. Overweight trucks or trucks that were inspected because of safety or driver credential concerns were also excluded because their longer times were not caused by waiting in line. The time to transit the station for each truck is the number of minutes from when it was created on an origin link to when it left the simulation on a destination link. As expected, the average time is proportional to the average queue length. Thus the drawback to longer ramps is that trucks must wait in the queue longer before being weighed. The increase from the base scenario to the 1000 foot longer ramp scenario is about 2 minutes. The increase from the base scenario to the 2000 foot longer ramp scenario is about 5 minutes. The longer times on the longer ramps also have a greater standard deviation. The differences in mean value for the transponder scenarios were not statistically significant. The mean value for the WIM scenario is significantly lower because the average queue length is significantly shorter.

	Base Case	Ramp +1000 feet	Ramp + 2000 feet	5% Trans-ponder	10% Trans-ponder	20% Trans-ponder	30% Trans-ponder	40% Trans-ponder	50% Trans-ponder	WIM Scale
Mean	10.27	13.79	18.51	9.00	8.94	8.82	8.58	8.52	7.88	3.60
Std. Deviation	0.35	0.33	0.35	0.00	0.00	-1.00	-1.00	-1.00	-1.00	-1.00
Statistical Significance		100%	100%	100%	100%	100%	100%	100%	100%	100%
Difference is Significant?		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

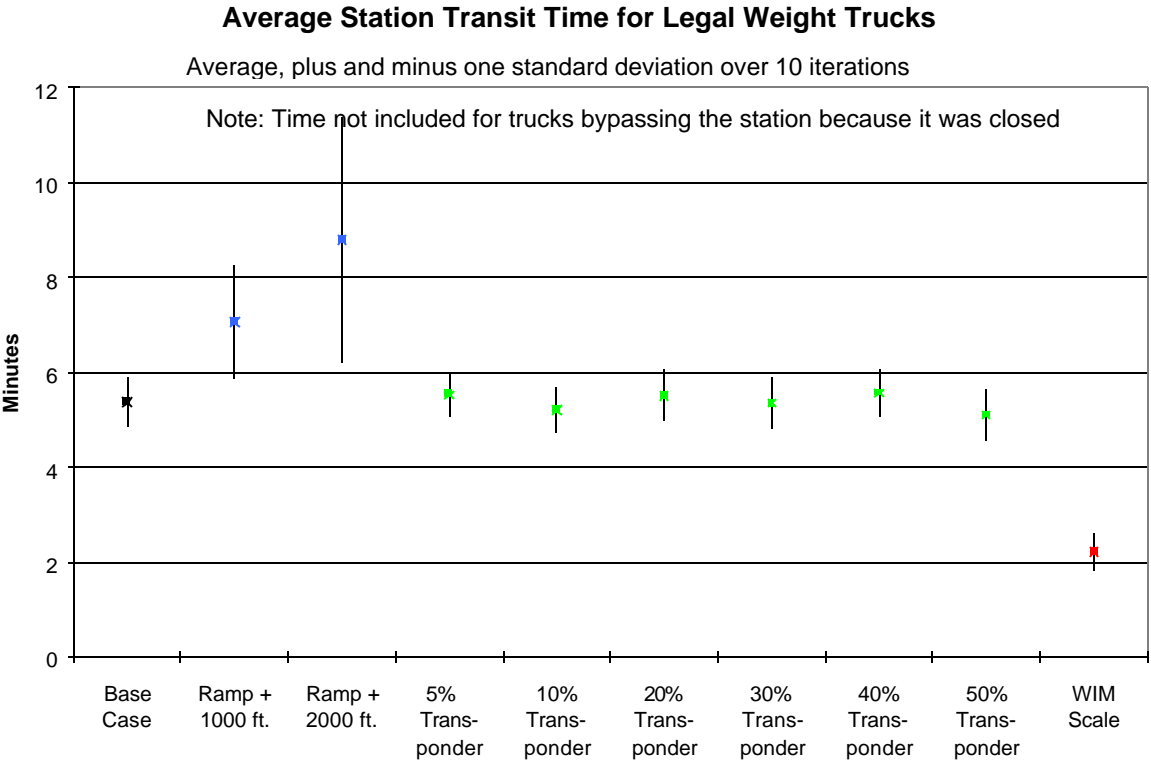
**Table 6-5. Statistics for Average Time to Transit Station**

### 6.1.6 Average Hard Deceleration on Station Entrance Ramp

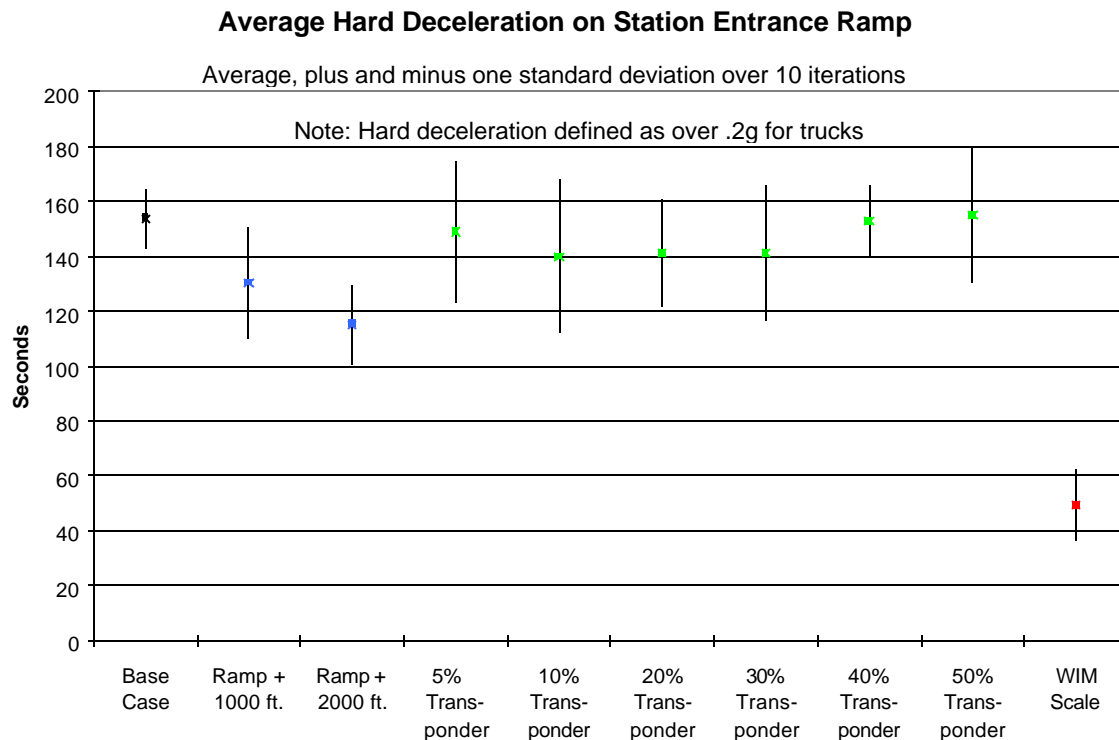
Table 6-6 and figure 6-6 show the average number of seconds of hard deceleration for trucks on the station entrance ramp. As explained in section 2, Mitretek's threshold of hard deceleration for a truck is 0.2g. In perfect driving conditions, hard deceleration would never be necessary. However, variations in driver attentiveness, reaction time, speed, and brake performance result in some cases where harder braking than average is necessary to avoid a collision. Westa does not try to predict collisions, but uses the measure of hard deceleration as a surrogate measure of safety. Hard braking on link 21 is typically caused by trucks having to brake harder than expected to avoid hitting the truck at the tail end of the line. This last truck may be close to the highway if the ramp is nearly full.

	Base Case	Ramp +1000 feet	Ramp + 2000 feet	5% Trans-ponder	10% Trans-ponder	20% Trans-ponder	30% Trans-ponder	40% Trans-ponder	50% Trans-ponder	WIM Scale
Mean	153.85	130.29	115.18	148.99	139.97	141.23	141.18	152.75	154.96	49.24
Std. Deviation	11.06	20.47	14.47	26.17	28.16	19.36	24.98	13.00	24.70	13.09
Statistical Significance		100%	100%	40%	84%	91%	84%	16%	10%	100%
Difference is Significant?		Yes	Yes	No	No	Yes	No	No	No	Yes

**Table 6-6. Statistics for Hard Deceleration on Entrance Ramp**



**Figure 6-5. Average Time to Transit Station**



**Figure 6-6. Average Number of Seconds of Hard Braking on Station Entrance Ramp**

Both scenarios with longer ramps show a reduction in the amount of hard braking on the station entrance ramp. Since the ramp is longer, the average position of the end of the tail truck is farther along the ramp than for the standard ramp length. Thus trucks entering the ramp have more time on the average to stop and can stop more gradually. For the WIM scenario, the average queue length is significantly shorter, so trucks have more room to stop gradually as well. The average values for the transponder scenarios are not significantly different from that of the base case scenario.

#### 6.1.7 Average Hard Deceleration on Highway as Trucks Merge

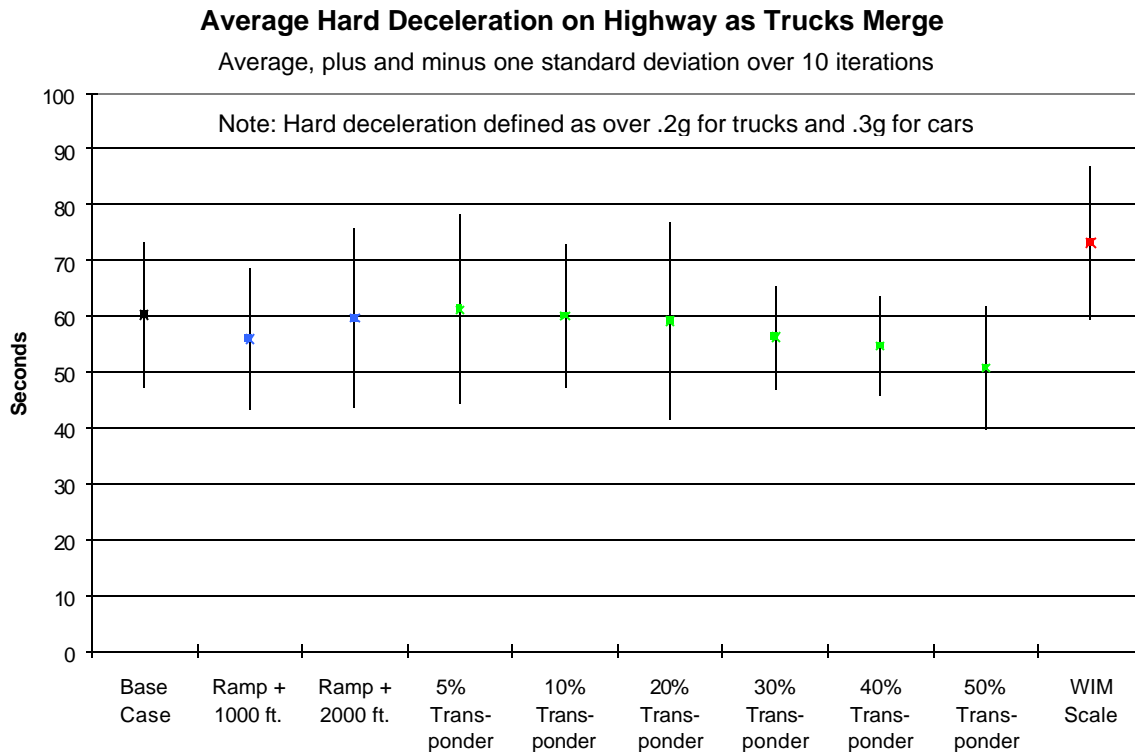
Table 6-7 and figure 6-7 show the average number of seconds of hard deceleration for cars and trucks on the right lane of the highway approaching the spot where trucks exiting the station merge onto the highway. Mitretek's threshold of hard deceleration for a car is 0.3g. Cars may shift to the left lane to avoid slowing down at this spot, but sometimes a lane shift is not possible. A truck in this position has bypassed the station, either because of station closing or because it had a transponder. For all the scenarios except the WIM scenario, the amount of deceleration at this point is roughly the same. Because of the high standard deviations, there is no statistically significant difference. The average value for the WIM scenario, however, is significantly higher. This is because in the WIM scenario all trucks exit the highway and must re-enter the highway at the merge point. In all other scenarios, a significant number of trucks bypassed the station, so the rate of trucks merging onto the highway was much lower. This statistic is the only statistic that is worse for the WIM scenario than the other scenarios.

	Base Case	Ramp +1000 feet	Ramp + 2000 feet	5% Transponder	10% Transponder	20% Transponder	30% Transponder	40% Transponder	50% Transponder	WIM Scale
Mean	60.25	55.89	59.60	61.23	60.05	59.13	56.27	54.73	50.74	73.19
Std. Deviation	13.04	12.67	16.06	16.93	12.99	17.73	9.34	8.88	11.26	13.85
Statistical Significance		54%	8%	11%	3%	13%	56%	72%	90%	95%
Difference is Significant?		No	No	No	No	No	No	No	Yes	Yes

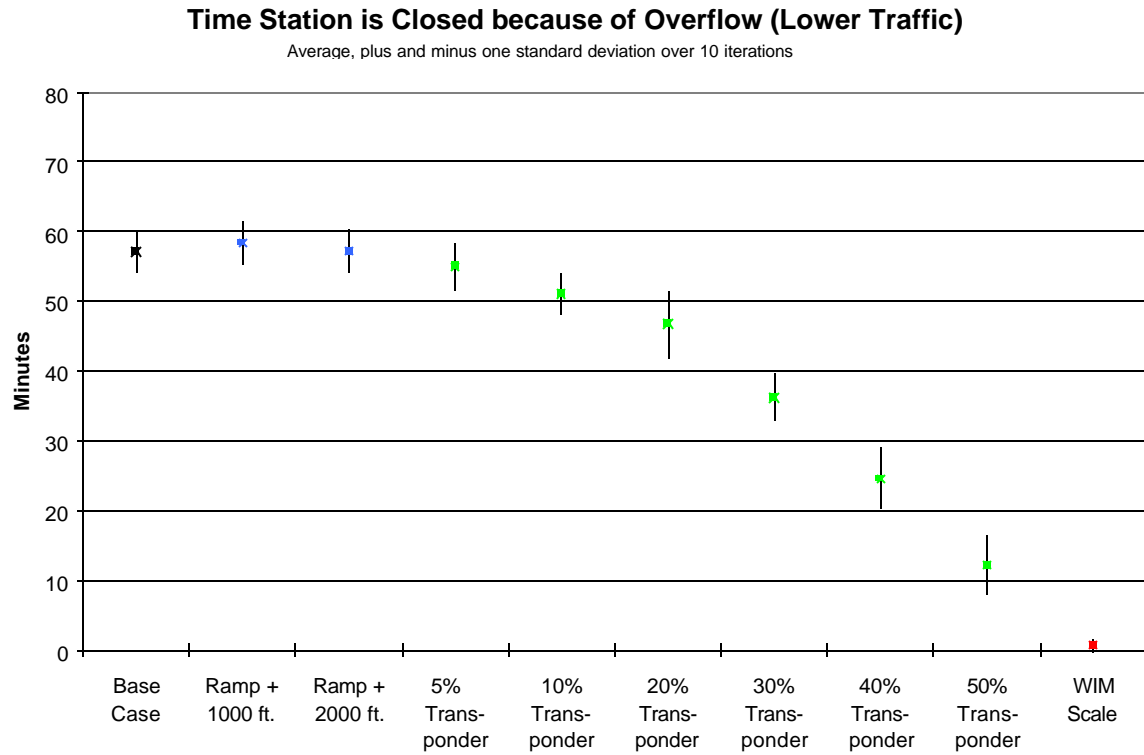
**Table 6-7. Statistics for Hard Deceleration on Highway Approaching Merge Area**

## 6.2 Results for Lower Traffic Demand Scenarios

To test whether the congestion reduction strategies would be effective at lower demand levels, Mitretek ran the same ten scenarios with traffic loads reduced by 20%. This was accomplished by increasing the vehicle interarrival rate from 2.56 seconds to 3.2 seconds. All vehicle classes were affected proportionately. The results of this set of scenarios did not differ significantly from the set of scenarios with the base arrival rate. Upon reflection, this is not surprising, because the number of trucks to be handled when all traffic is reduced by 20% is the same as the number of trucks to be handled for the 20% transponder scenario. In effect it is like adding 20% transponders to all the original scenarios. The number of cars in the simulation does not affect anything but the hard deceleration figures described in section 6.1.7. Figures 6-8 through 6-14 present the results for the reduced traffic scenarios. The commentaries on the results already provided in section 6.1 apply to this set of results as well.



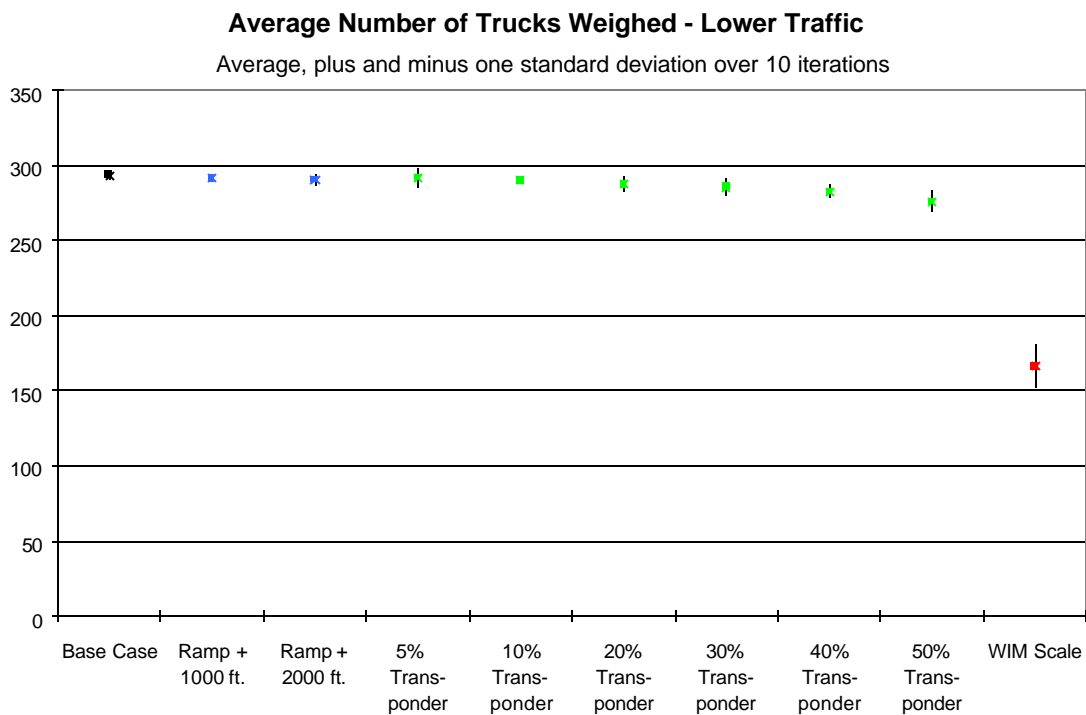
**Figure 6-7. Average Hard Deceleration for All Traffic on Highway Approaching Merge Area**



**Figure 6-8. Average Time Station is Closed – Lower Traffic Demand**



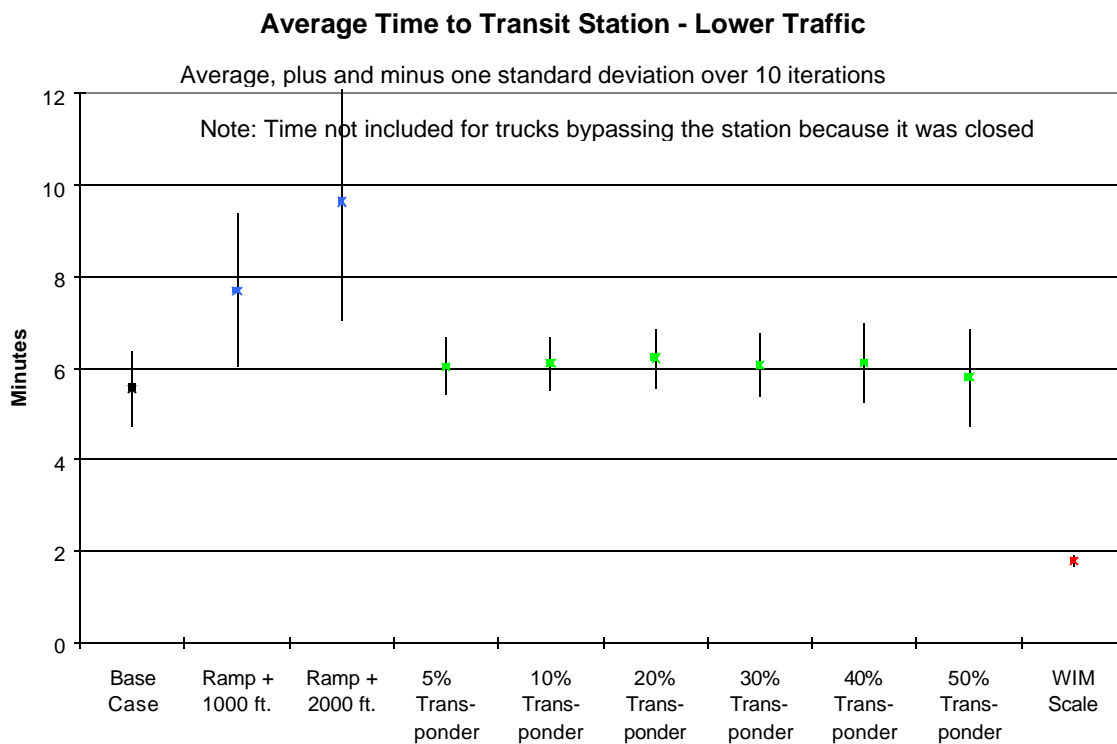
**Figure 6-9. Average Percent of Overweight Trucks Missed – Lower Traffic Demand**



**Figure 6-10. Average Number of Trucks Weighed – Lower Traffic Demand**

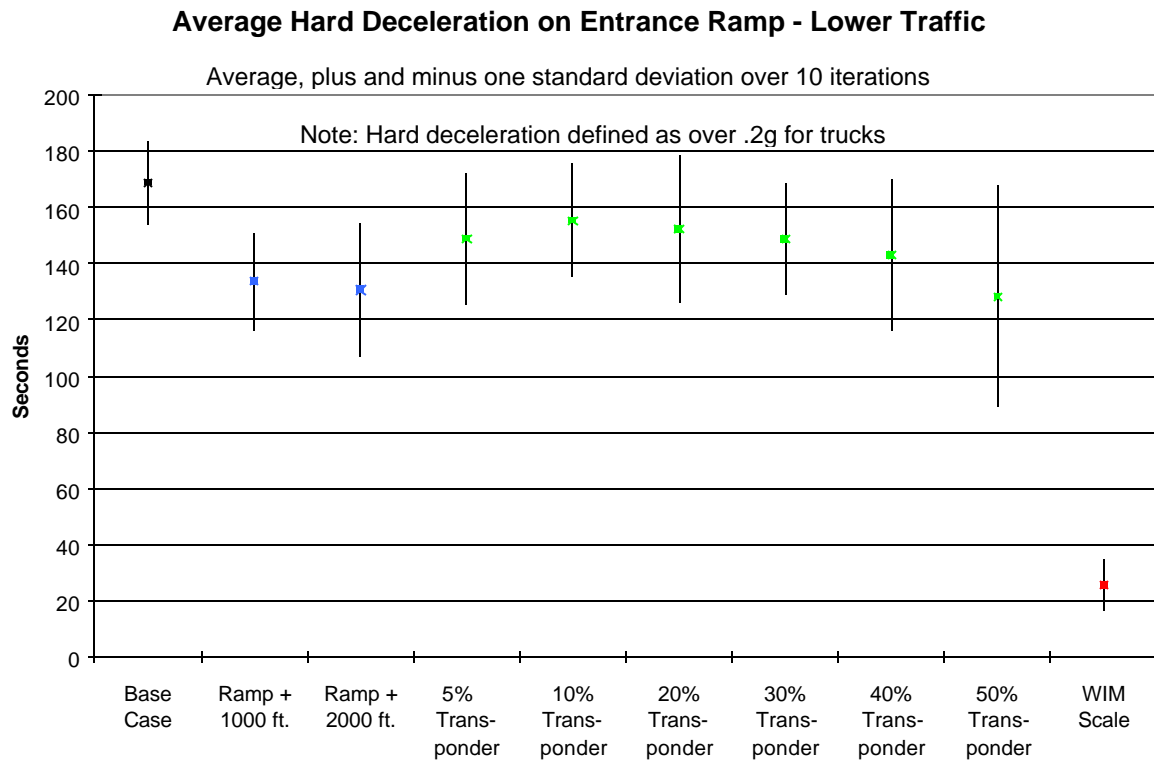


**Figure 6-11. Average Queue Length – Lower Traffic Demand**

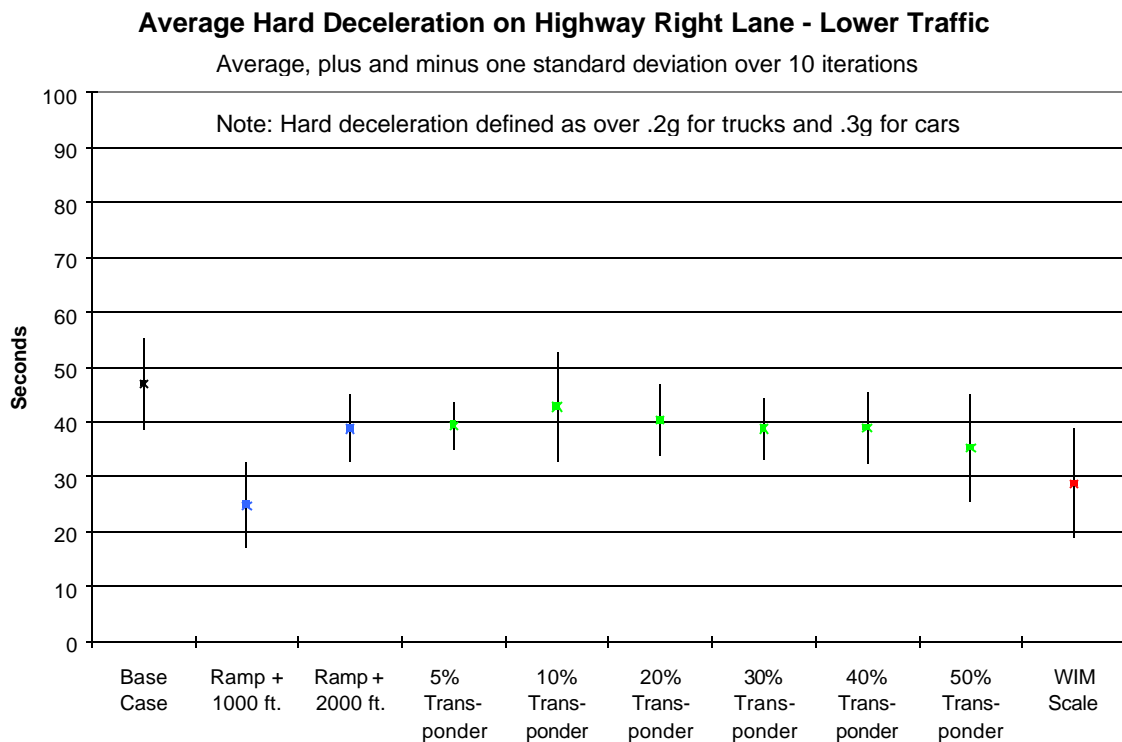


**Figure 6-12. Average Time to Transit Station – Lower Demand Scenario**





**Figure 6-13. Average Hard Deceleration on Entrance Ramp – Lower Traffic Demand**



**Figure 6-14. Average Hard Deceleration Approaching Merge Area – Lower Traffic Demand**

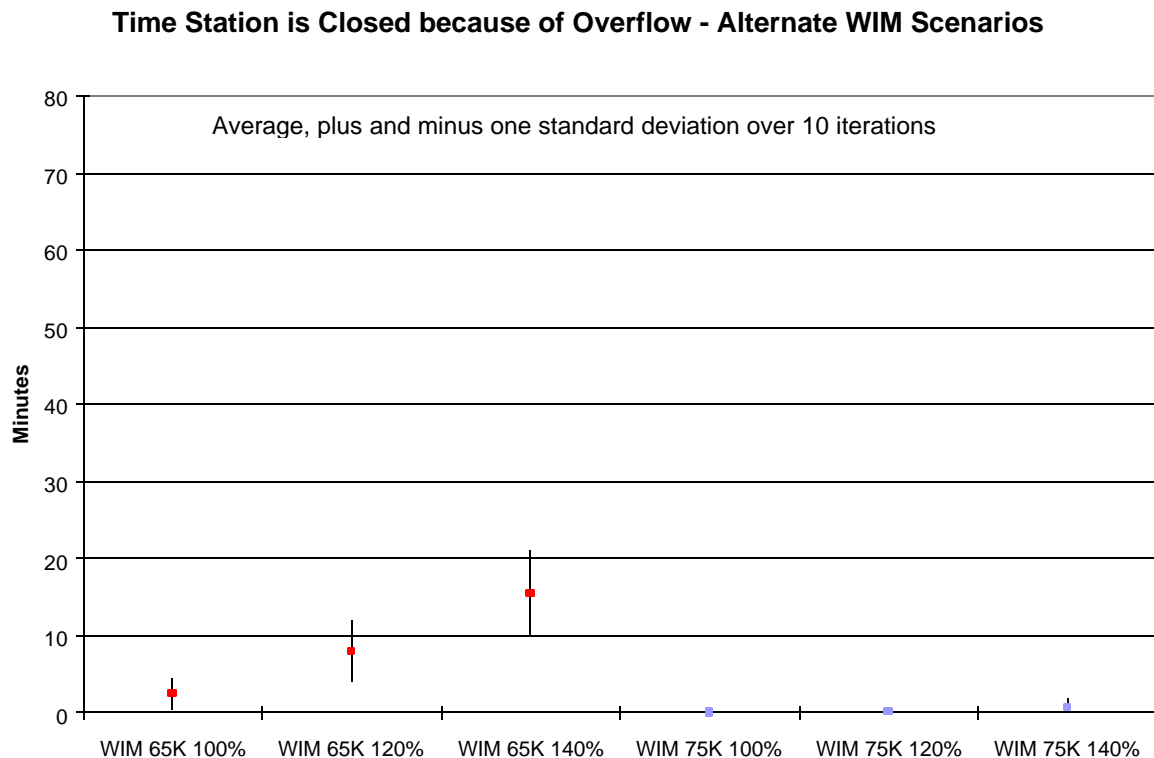
### 6.3 Results for Alternate WIM Scenarios

Since the WIM scenario nearly eliminated congestion at the weigh station with the base rate of arrivals, Mitretek ran scenarios of the WIM scenario with the traffic load increased by 20% and 40%. These increased arrival rates are consistent with the forecast of the rate of growth in truck miles and ton-miles from the trucking industry's Team 2000<sup>6</sup>. Mitretek also ran the same three scenarios (base arrival rate plus two increased arrival rates) for the scenario where the threshold for bypassing trucks weighed by the WIM scale was set at 75,000 pounds rather than 65,000 pounds.

This section presents the results of this series of simulation runs. The scales for all the plots are the same as those used in sections 6.1 and 6.2. The scenarios in all figures in this section are identified by the WIM threshold of 65,000 or 75,000 pounds and the arrival rate of 100%, 120% or 140% of the base arrival rate. The averages for the three 65K scenarios are shown as red squares and the averages for the three 75K scenarios are shown as purple squares. The first scenario in each plot (65K threshold, 100% arrival rate) is the same as the WIM case in section 6.1.

#### 6.3.1 Time Station is Closed

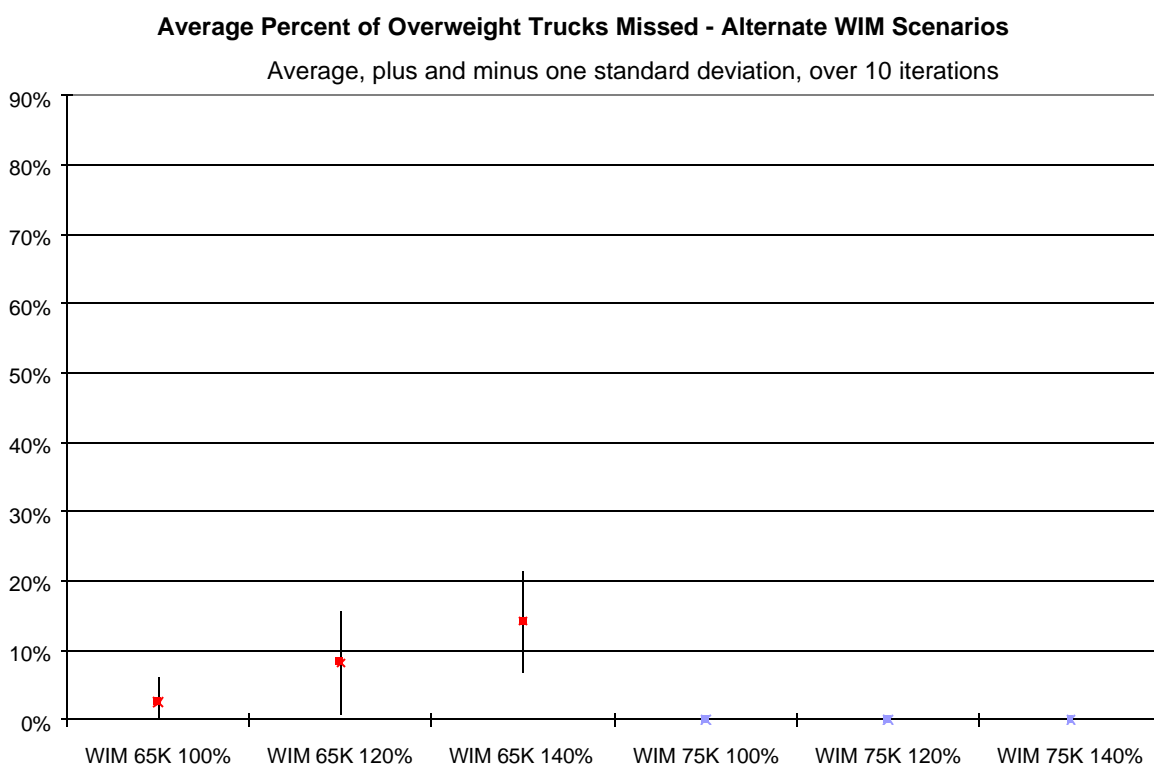
Figure 6-15 presents the average time (in minutes) the station was closed because of queue overflow, out of the two hours modeled in the simulation. All the times are significantly lower than the scenarios without a WIM scale. When the WIM threshold was changed from 65,000 pounds to 75,000 pounds, the number of trucks to be weighed decreased significantly, so the queue did not back up as often.



**Figure 6-15. Time Station is Closed – Alternate WIM Scenarios**

### 6.3.2 Number of Overweight Trucks Missed

Figure 6-16 presents the average proportion of overweight trucks missed, computed as the number of overweight trucks that bypassed the station when the station was closed divided by the total number of overweight trucks. The results are roughly proportional to the amount of time the station was closed. That stands to reason, because overweight trucks are generated throughout the simulation, and the chance of an overweight truck approaching the station at a time when it is closed is proportional to the chance the station is closed. As the traffic level increased, the number of times the station was closed increased and the proportion of bypassed overweight trucks increased. Although the station was occasionally closed for the scenarios with a WIM threshold of 75,000 pounds, no overweight trucks happened to come along during those station closings.

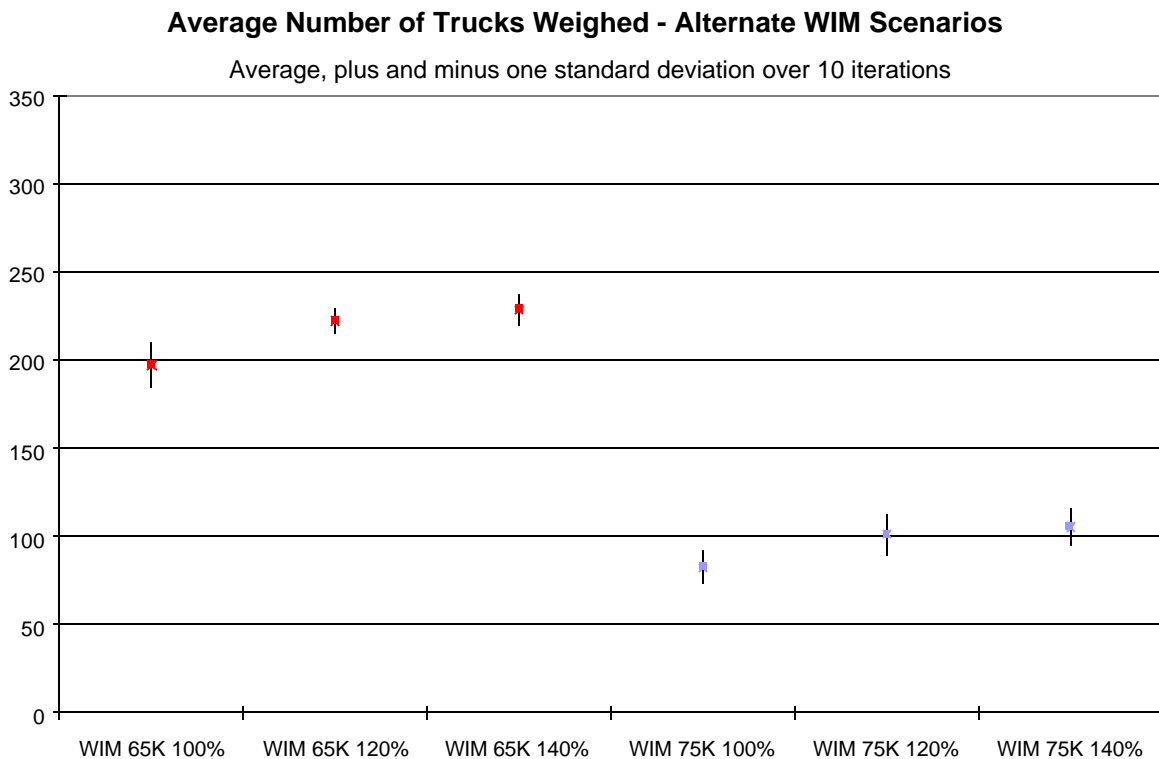


**Figure 6-16. Average Percent of Overweight Trucks Missed – Alternate WIM Scenarios**

### 6.3.3 Average Number of Trucks Weighed

Figure 6-17 shows the average number of trucks weighed for each alternate WIM scenario. For the base arrival rate with the WIM threshold of 65,000 pounds, the scales were empty some of the time. As the traffic level increased, the number of trucks weighing over the threshold increased proportionately, and the scales were busy a greater percent of the time. The maximum number of trucks to be weighed in two hours would be 288, as explained in section 6.1.3.

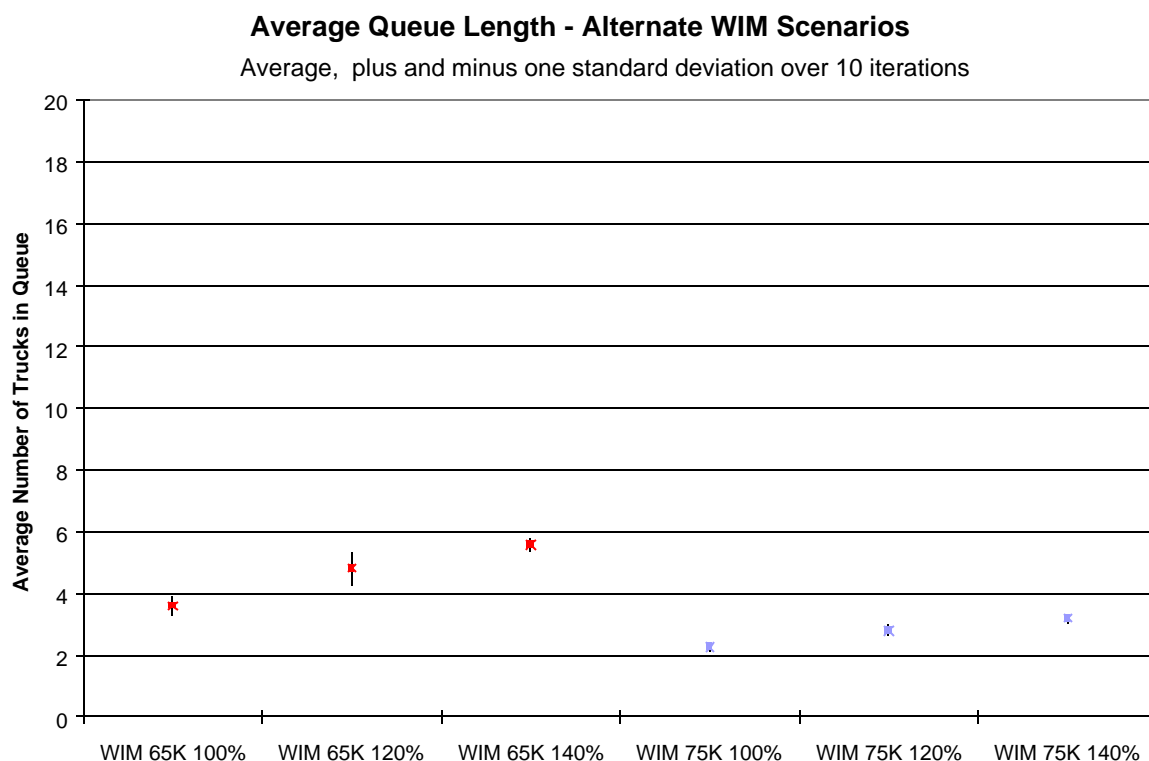
With a WIM threshold of 75,000 pounds, the static scales could handle every truck over the threshold and still be empty a significant portion of the time. As the traffic level increased, the number of trucks weighing over the threshold increased proportionately, and the scales were busy a greater percent of the time.



**Figure 6-17. Average Number of Trucks Weighed – Alternate WIM Scenarios**

### 6.3.4 Average Queue Length

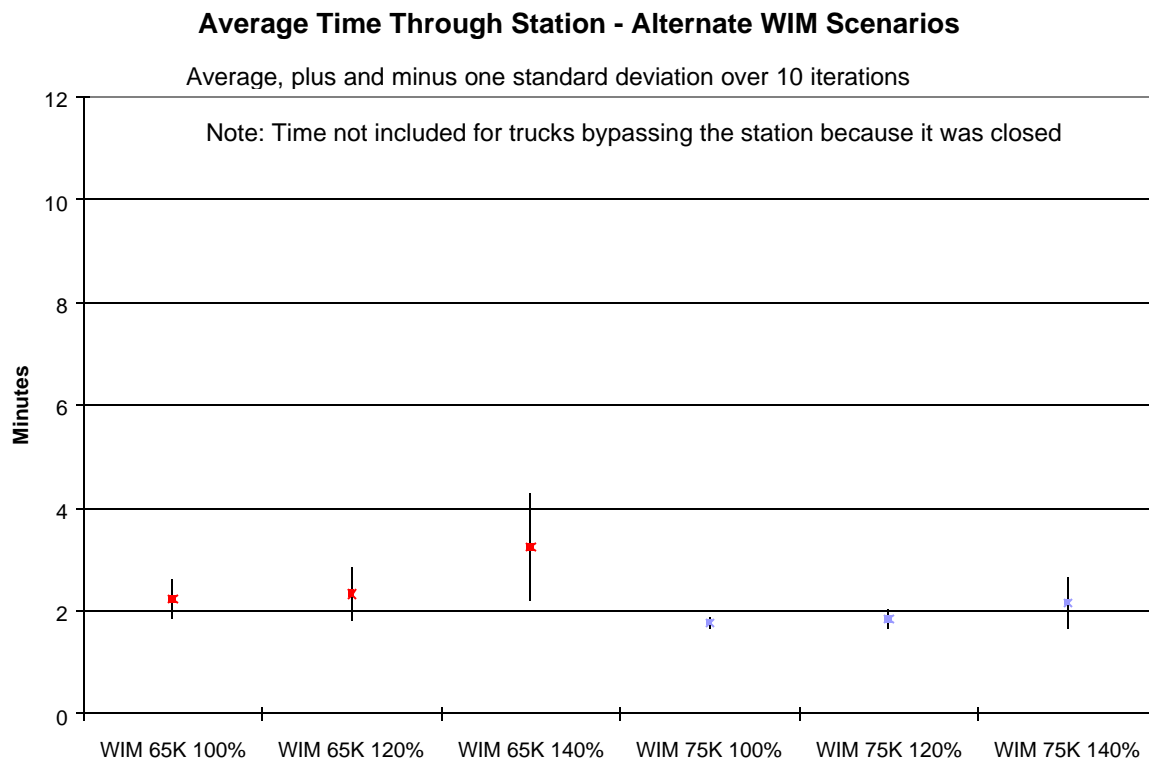
Figure 6-18 shows the average queue length over the course of the simulated two hours. This statistic included the count of all trucks on links 21, 22, and 23 up to the static scale. Unlike the scenarios in section 6.1.4 where the high arrival rate kept the average queue length at constant levels, the average queue length for this set of scenarios was roughly proportional to the arrival rate. This result is predicted by basic queuing theory. Even at the highest arrival rate, the average queue length is significantly less than the average queue length for the base scenario and the transponder scenarios shown in section 6.1.4.



**Figure 6-18. Average Queue Length – Alternate WIM Scenarios**

### 6.3.5 Average Time to Transit Station

Figure 6-19 shows the average amount of time to transit the station for trucks of legal weight that entered the station. As expected, the average time is proportional to the average queue length. The mean value for the WIM scenarios is significantly lower than for the other scenarios because the average queue length is significantly shorter. As the traffic level increased, the average queue length increased and the average time spent by trucks waiting in the queue increased.

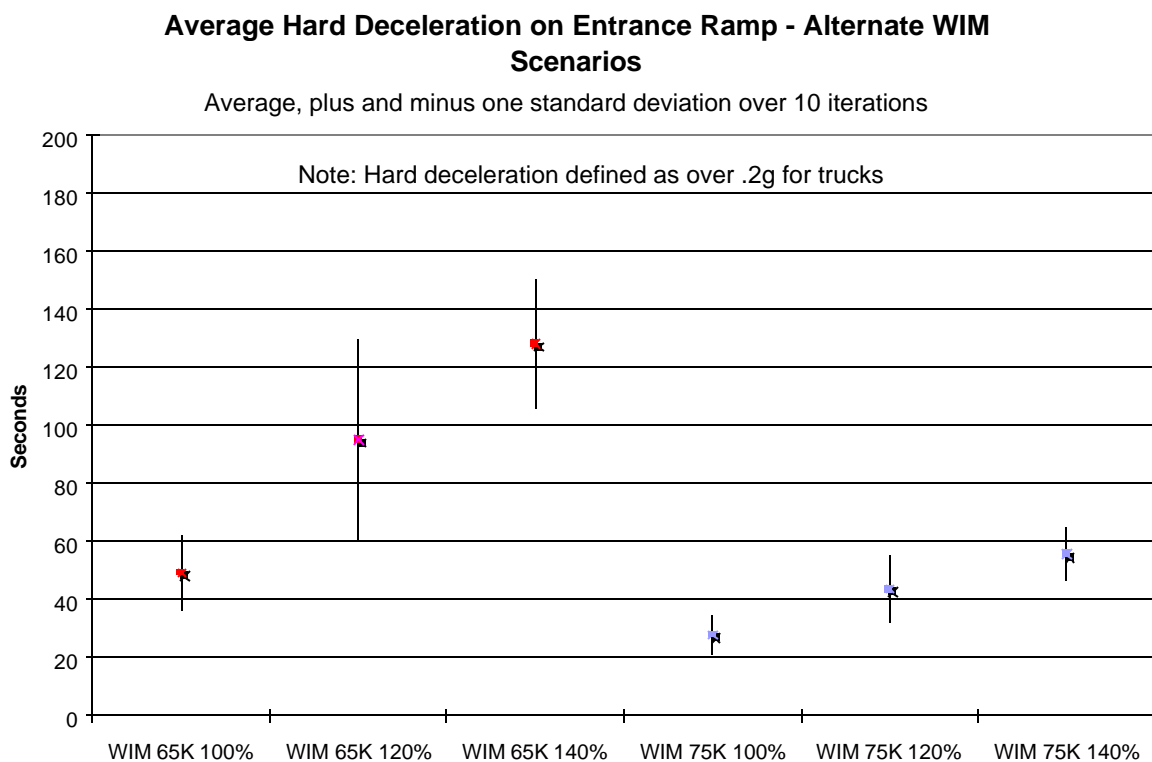


**Figure 6-19. Average Time to Transit Station – Alternate WIM Scenarios**

### 6.3.6 Average Hard Deceleration on Station Entrance Ramp

Figure 6-20 shows the average number of seconds of hard deceleration for trucks on the station entrance ramp. As explained in section 2, Mitretek's threshold of hard deceleration for a truck is 0.2g. In perfect driving conditions, hard deceleration would never be necessary. However, variations in driver attentiveness, reaction time, speed, and brake performance result in some scenarios where harder braking than average is necessary to avoid a collision. Westa does not try to predict collisions, but uses the measure of hard deceleration as a surrogate measure of safety. Hard braking on link 21 is typically caused by trucks having to brake harder than expected to avoid hitting the truck at the tail end of the line. This last truck may be close to the highway if the ramp is nearly full.

The average queue length is significantly shorter for the WIM scenario than the other scenarios, so trucks have more room to stop gradually as well. As the level of traffic increased, the queue length increased as the number of sudden stops on the entrance ramp increased proportionately.

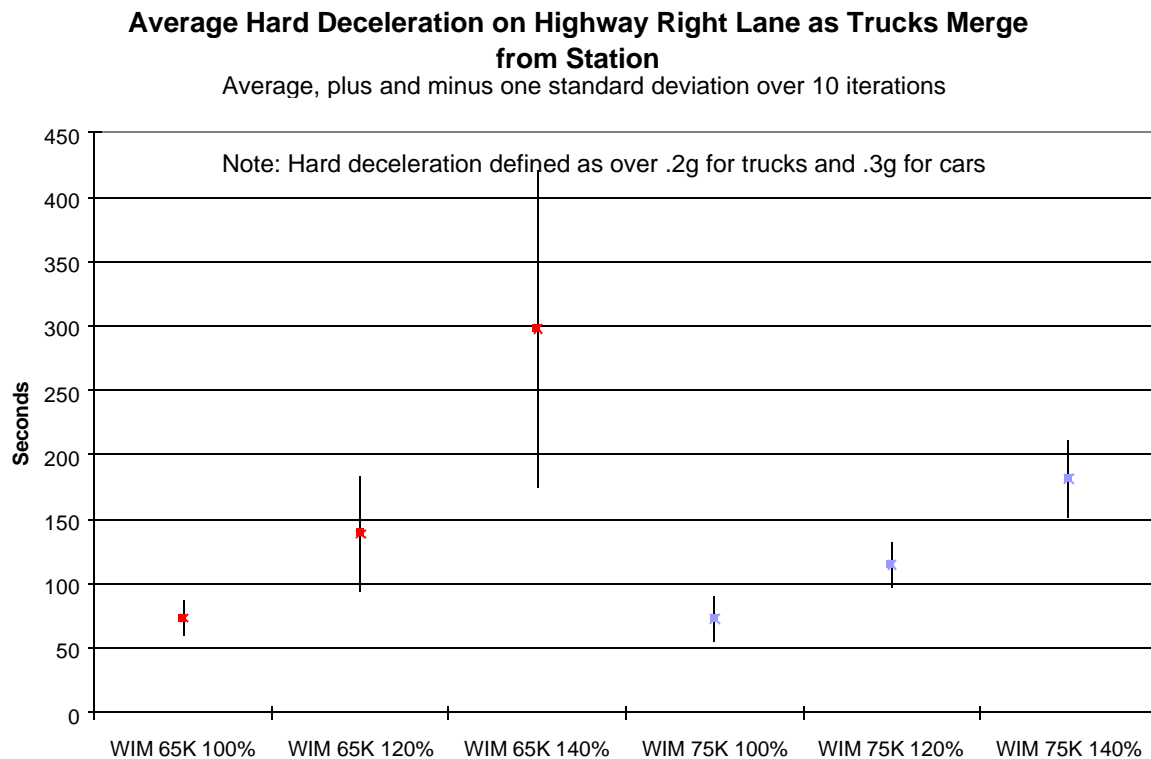


**Figure 6-20. Average Number of Seconds of Hard Braking on Station Entrance Ramp – Alternate WIM Scenarios**

### 6.3.7 Average Hard Deceleration on Highway as Trucks Merge

Figure 6-21 shows the average number of seconds of hard deceleration for cars and trucks on the right lane of the highway approaching the spot where trucks exiting the station merge onto the highway. Mitretek's threshold of hard deceleration for a car is 0.3g. Cars may shift to the left lane to avoid slowing down at this spot, but sometimes a lane shift is not possible. A truck in this position has bypassed the station, either because of station closing or because it had a transponder.

As noted in section 6.1.7, this statistic is higher for the WIM scenarios than for all the others, because the station is rarely closed, and almost all trucks must enter the station and reenter the highway. As the traffic level increased, this measure of deceleration also increased significantly. This graph could not be plotted on the same scale as figure 6-7 because the values exceed the scale of that figure. Before taking the highest values too seriously, it may be well to examine the merging and lane-changing algorithms used by Westa to determine whether they still hold realistically at high traffic levels.



**Figure 6-21. Average Hard Deceleration for All Traffic on Highway Approaching Merge Area – Alternate WIM Scenarios**





## Section 7

# Results for McCook Port of Entry

Mitretek ran ten iterations for each of the nine scenarios using different random seeds for each iteration. Each iteration produced a summary file, from which the following values were extracted:

- ◆ Total number of trucks
- ◆ Total number of trucks that were weighed
- ◆ Total number of overweight trucks and trucks with safety or credential problems
- ◆ Total number of trucks not weighed when the scales were closed
- ◆ Total number of overweight trucks or trucks with safety or credential problems not inspected because of scale closing
- ◆ Average time to transit the station spent by legal weight trucks
- ◆ Average queue length for the static scale
- ◆ Total time during the simulation that the scales were closed because of queue overflow
- ◆ Total seconds of hard deceleration (greater than 0.2g) for trucks
- ◆ Total seconds of hard deceleration (greater than 0.3g) for cars

The results are presented and plotted for each scenario. For each measure of effectiveness, a table presents the average value  $\Sigma x_i/10$  and the standard deviation  $\sqrt{(\Sigma x_i^2/10)}$ . The table then presents the statistical significance from two  $\chi^2$  (chi-square) tests. The first  $\chi^2$  test compares the results the ten iterations of an alternate scenario against the ten iterations of the base scenario with the same traffic volume. The second  $\chi^2$  test compares the results for the ten iterations of a scenario with increased traffic levels against the ten iterations of the same scenario but the base traffic volume. Thus it is apparent which changes are due to the different station configuration or operating policy and which changes are due to increased traffic levels. If the level of significance is greater than 90% or 95%, there is high confidence that the alternate scenario does indeed make a significant difference to the average value of the measure of effectiveness. If the level of significance is less than 90%, it cannot be said that the alternative scenario has a different result than the base scenario.

Following each table, a plot shows the average value across the 10 iterations for each scenario. The averages for the three traffic volumes for the base case scenario are blue squares, the averages for the first alternate scenario are red squares, and the averages for the second alternate scenario are green squares. Each plot also features vertical bars indicating one standard deviation above and below the average for each scenario. If the standard deviation is large in relation to the difference between the average value for the base scenario and the average value for an alternate scenario, then the difference in the average value is not likely to be statistically significant. In general, the smaller the standard deviation, the more likely results are to have high values of statistical significance.

### 7.1 Average Scales Closed Time

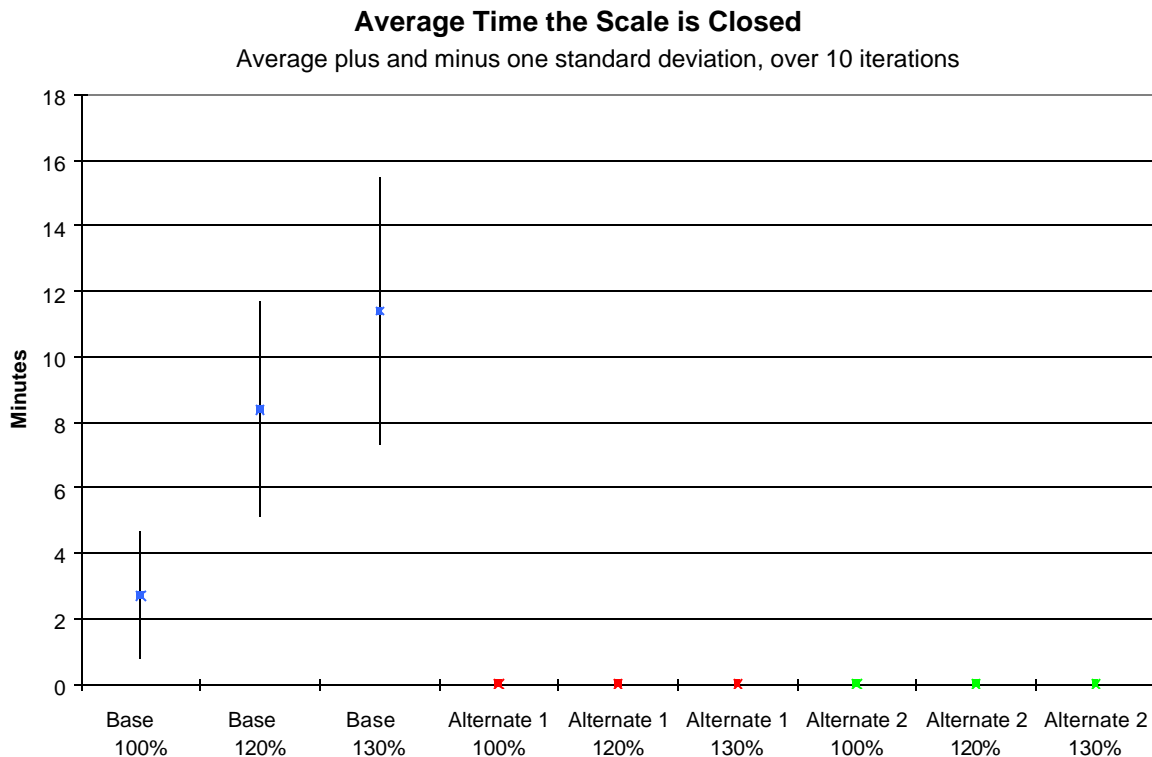
Table 7-1 and figure 7-1 present the average time (in minutes) the scales were closed because of queue backup. The amount of time represented by the simulation was two hours.

The key input values driving this result were the arrival rate of trucks and the average time to weigh a truck. Based on data collected by SDDOT when the scales were closed twice during the two days of

observation, the results obtained from the base scenario do not seem unreasonable. SDDOT has confirmed that the results are consistent with their experience.

Minutes scales are closed	Base 100%	Base 120%	Base 130%	Alt. 1 100%	Alt. 1 120%	Alt. 1 130%	Alt. 2 100%	Alt. 2 120%	Alt. 2 130%
Mean	2.71	8.38	11.40	0.00	0.00	0.00	0.00	0.00	0.00
Std. Deviation	1.96	3.30	4.08	0.00	0.00	0.00	0.00	0.00	0.00
Statistical Significance:									
Compared to base case same volume				100%	100%	100%	100%	100%	100%
Difference is Significant?				Yes	Yes	Yes	Yes	Yes	Yes
Compared to same case base volume		100%	100%		N/A	N/A		N/A	N/A
Difference is Significant?		Yes	Yes		N/A	N/A		N/A	N/A

**Table 7-1. Statistics for the Number of Minutes the Scales are Closed**



**Figure 7-1. Average Time Scales are Closed**

For the base case scenario, increasing traffic volumes clearly led to more times the scales were closed. This result is consistent with basic queuing theory, comparing the arrival rate of trucks to the service rate. Under the highest growth scenario, the scales were closed nearly ten percent of the time.

The WIM scale for the first alternate case effectively removed over 95% of the trucks from the static scales, so there was no backup of trucks waiting to be weighed. In other words, the arrival rate of trucks to be weighed was well below the rate at which they could be weighed. Therefore the time the station was closed was reduced to zero. It should be noted that if the queue of trucks waiting for the

static scale were to back up past the point where the bypass lane diverged from the entrance ramp, then underweight trucks would be stuck briefly in the queue as well. However, for this scenario the queue backup never extended so far as to cause the scales to close.

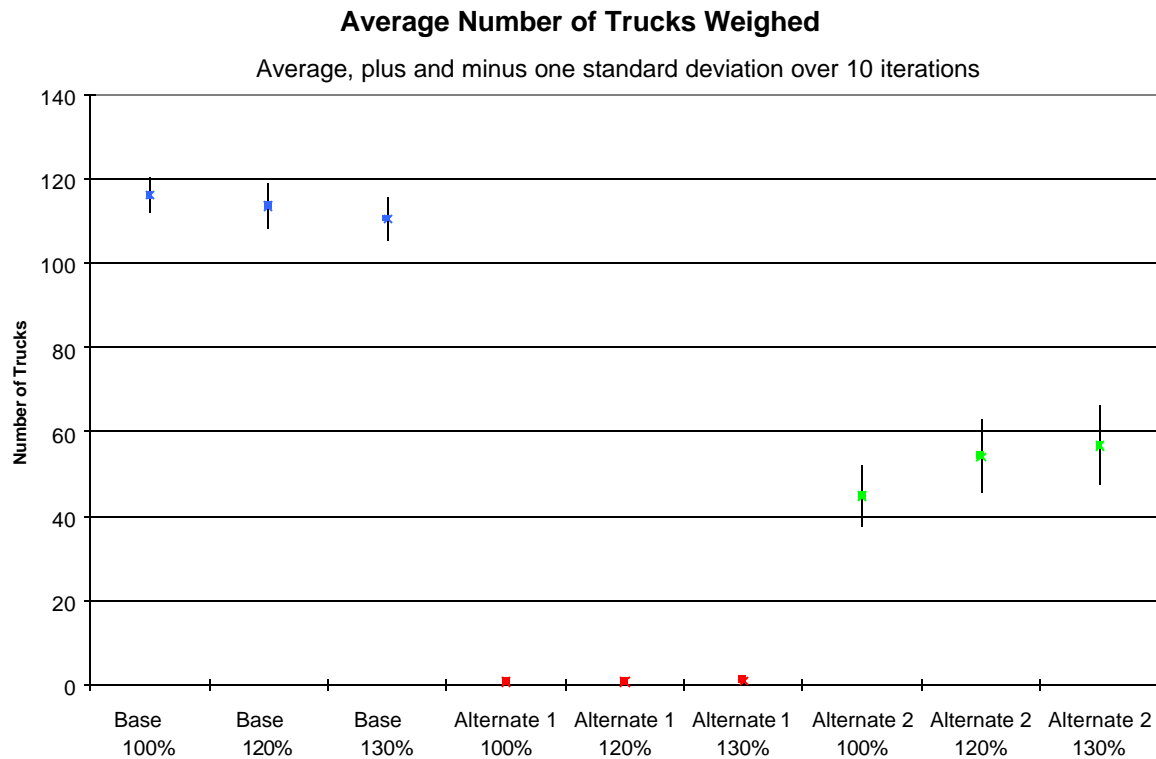
The second alternate case, with all trucks measured over the 70,000 pound gross weight threshold sent to the scales, likewise did not experience sufficient backup to close the scales. The reduction in the number of trucks to be weighed was so significant that further reduction was not necessary to prevent queue backup.

## 7.2 Average Number of Trucks Weighed

Table 7-2 and figure 7-2 show the average number of trucks weighed for each scenario. For the base case scenarios, this number did not increase with traffic volume. This fact suggests that the effective maximum number of trucks that can be weighed had already been reached, and any additional traffic was spilled over as bypasses (see table 7-3 and figure 7-3). In fact, the number weighed decreased slightly, since the scales were closed more frequently to empty out the queue.

Number weighed	Base 100%	Base 120%	Base 130%	Alt. 1 100%	Alt. 1 120%	Alt. 1 130%	Alt. 2 100%	Alt. 2 120%	Alt. 2 130%
Mean	116.20	113.60	110.60	0.60	0.60	0.90	44.70	54.10	56.70
Std. Deviation	4.39	5.46	5.23	0.84	0.84	0.99	7.50	8.81	9.58
Statistical Significance:									
Compared to base case same volume				100%	100%	100%	100%	100%	100%
Difference is Significant?				Yes	Yes	Yes	Yes	Yes	Yes
Compared to same case base volume		74%	98%		0%	52%		98%	99%
Difference is Significant?		No	Yes		No	No		Yes	Yes

**Table 7-2. Statistics for Number of Trucks Weighed**



**Figure 7-2. Average Number of Trucks Weighed**

The effective maximum number of trucks that can be weighed in an hour is a function of the average time to weigh a truck (including the longer time spent by some overweight trucks) and the time between trucks from when one truck begins to leave the scale to when the next truck is in place ready to be weighed.

The number of trucks weighed for the first alternate scenario with a WIM scale was almost zero because only one percent of the trucks were over 80,000 pounds gross weight, and only 20% of the those were sent to the static scales. The number of trucks weighed for the second alternate scenario is much greater than for the first alternate scenario because all trucks measured over 70,000 pounds gross weight by the WIM scale were sent to the static scale. For this scenario the increase in number weighed with traffic volume is evident. The difference is statistically significant because of the small standard deviations.

### 7.3 Average Number of Trucks Bypassed

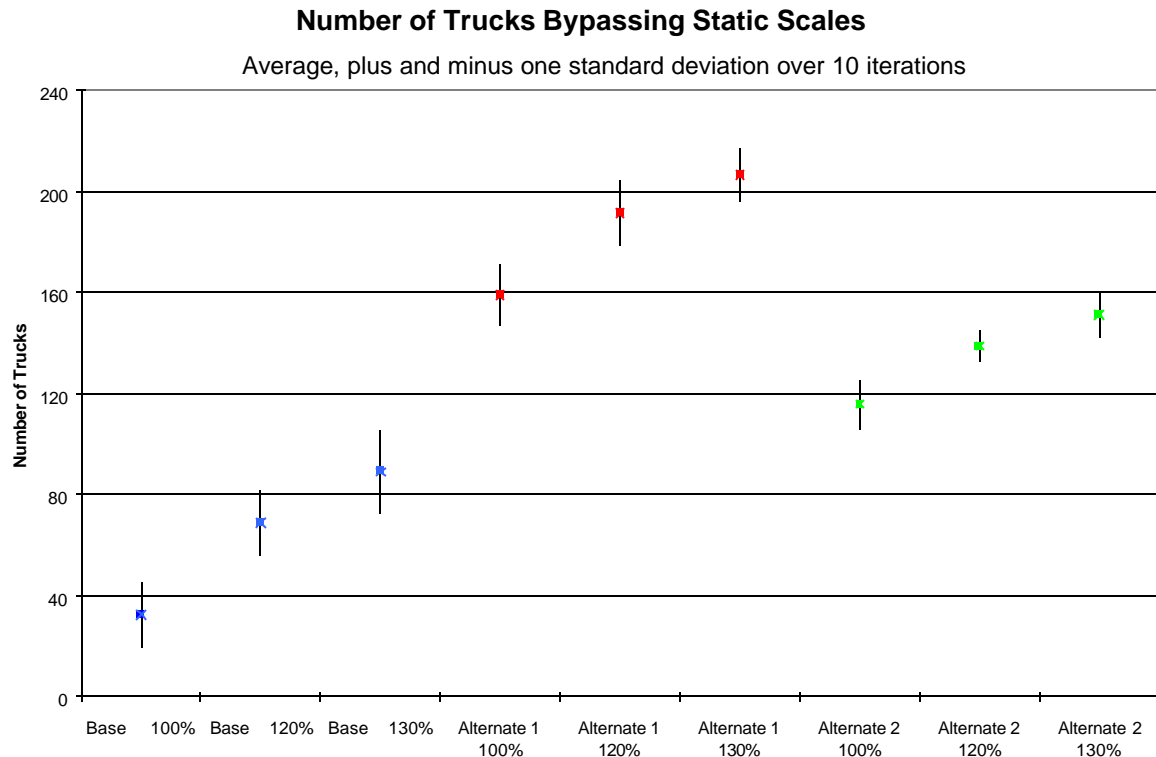
Table 7-3 and figure 7-3 show the average number of trucks that bypassed the static scale for each scenario. For the base case scenarios, this is the number of trucks that were waved past the scales when the scales were closed. For the first alternate scenario, this number is all legal weight trucks plus 80% of the overweight trucks. For the second alternate scenario, this number is all trucks measured under the 70,000 pound WIM threshold.

For the base scenario, this number increased as the traffic level increased. More frequent long queues caused the scales to close more frequently, and more trucks bypassed the scales during those times.

For the first alternate scenario, most trucks bypassed the scales, and the number to do so is directly proportional to the total traffic load. For the second alternate scenario, the number of bypasses is less because all trucks weighted over 70,000 pounds were sent to the static scales. In this scenario as well, the number to do so was directly proportional to the total traffic load. All differences were statistically significant.

Number bypassed	Base 100%	Base 120%	Base 130%	Alt. 1 100%	Alt. 1 120%	Alt. 1 130%	Alt. 2 100%	Alt. 2 120%	Alt. 2 130%
Mean	32.40	68.90	89.10	159.00	191.50	206.60	115.80	138.70	151.20
Std. Deviation	12.88	13.19	16.78	12.53	13.05	10.59	9.92	6.07	9.02
Statistical Significance:									
Compared to base case same volume				100%	100%	100%	100%	100%	100%
Difference is Significant?				Yes	Yes	Yes	Yes	Yes	Yes
Compared to same case base volume		100%	100%		100%	100%		100%	100%
Difference is Significant?		Yes	Yes		Yes	Yes		Yes	Yes

**Table 7-3. Statistics for Number of Trucks Bypassed**



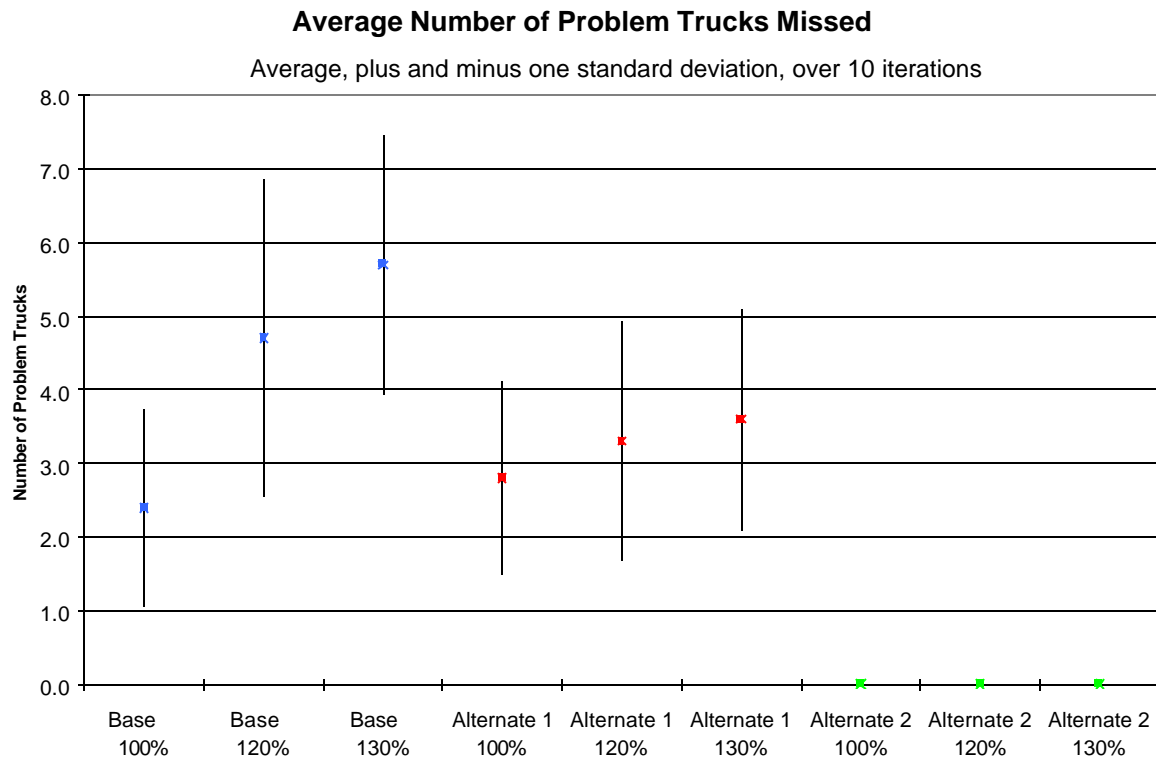
**Figure 7-3. Average Number of Trucks Bypassing Static Scales**

#### 7.4 Average Number of Problem Trucks Missed

For each iteration, Mitretek counted the number of problem trucks missed as the sum of overweight trucks and trucks with safety or credential problems that were not weighed or inspected. For each scenario, Mitretek found the average percent of problem trucks missed across the ten iterations. Table 7-4 and figure 7-4 present the results.

Nbr problem trucks missed	Base 100%	Base 120%	Base 130%	Alt. 1 100%	Alt. 1 120%	Alt. 1 130%	Alt. 2 100%	Alt. 2 120%	Alt. 2 130%
Mean	2.40	4.70	5.70	2.80	3.30	3.60	0.00	0.00	0.00
Std. Deviation	1.35	2.16	1.77	1.32	1.64	1.51	0.00	0.00	0.00
Statistical Significance:									
Compared to base case same volume				87%	88%	88%	100%	100%	100%
Difference is Significant?				No	No	No	Yes	Yes	Yes
Compared to same case base volume		9%	53%		12%	6%		N/A	N/A
Difference is Significant?		No	No		No	No		N/A	N/A

**Table 7-4 Statistics for Number of Problem Trucks Missed**



**Figure 7-4. Average Number of Problem Trucks Missed**

For the base case scenarios, problem trucks were missed when the scales were closed because of queue backup. When the scales were closed, no trucks were weighed, and trucks with credential or safety problems were not identified and inspected. The average number of such trucks increased with increasing volume. That stands to reason, because problem trucks were generated throughout the simulation, and the chance of a problem truck approaching the scales at a time when they were closed is proportional to the chance the scales were closed. The standard deviation is relatively large because the number of problem trucks was relatively small, and it was largely a matter of chance whether problem trucks came along at a time the scales were closed.

For the proposed WIM operation, the problem trucks missed were those overweight trucks allowed to bypass the scales because they did not exceed axle weight limitations and were not part of the random sample. Thus it was fully intentional that overweight trucks bypassed the scales and may not be regarded as a problem at all. As expected, this number increased with increasing traffic volume. The

model assumes that trucks with safety or credential problems that are in the bypass lane are nevertheless spotted and directed to proceed to the inspection lot. Real-world experience indicates that it is problematic to spot these issues for trucks in a bypass lane.

In the second alternate case, all overweight trucks were weighed at the static scale, so none were missed. Likewise trucks with safety or credential problems that were in the bypass lane were spotted and directed to proceed to the inspection lot.

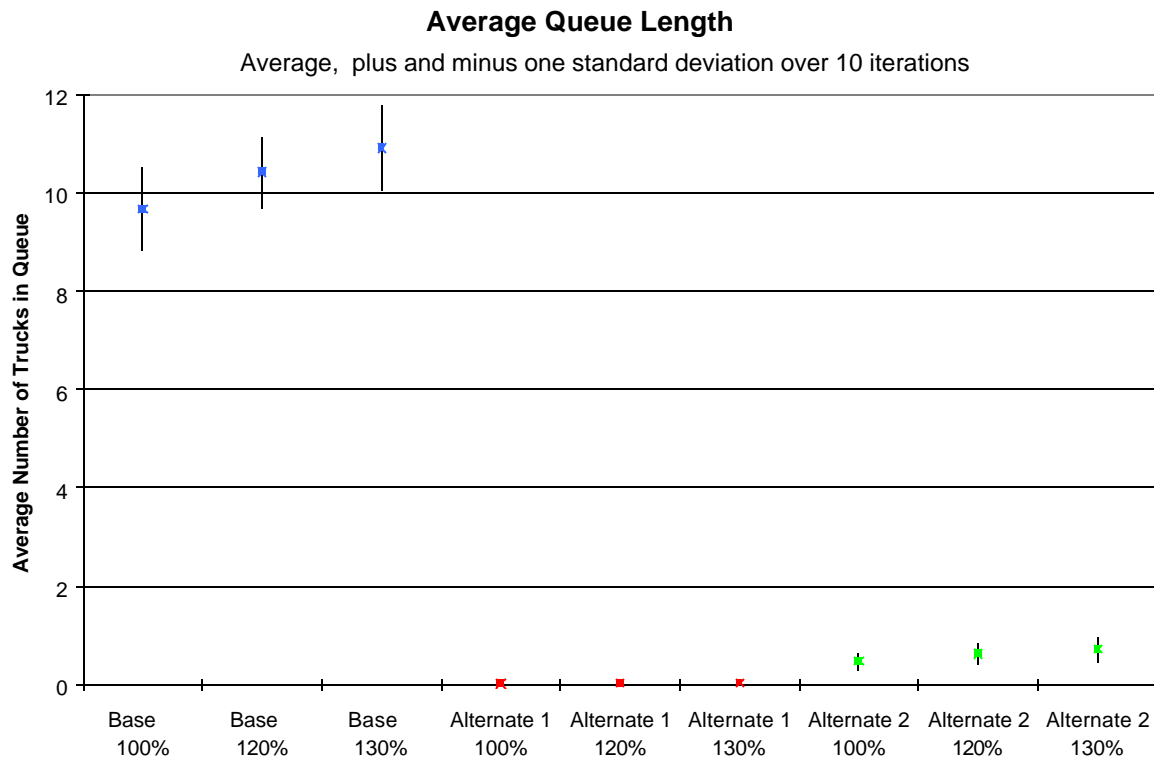
## 7.5 Average Queue Length

Table 7-5 and figure 7-5 show the average queue length over the course of the simulated two hours. This statistic included the count of all trucks on links 9, 10, and 11 up to the static scale. During the simulation the queue could be in any of the following states: (a) maximum value when trucks nearly reach the entrance to the ramp on the highway, causing the scales to close, (b) decreasing in size quickly if the scale is closed and trucks pass by without stopping, (c) decreasing in size slowly if trucks are being weighed at the scale at a rate faster than new trucks arrive, or (d) growing, if trucks are being weighed at the scale at a rate slower than new trucks arrive. Most of the time, the queue did not extend back to the highway and the scales did not close. The number of trucks that fit on each link is not constant because of the variations in truck length, but it doesn't change much.

Queue length	Base 100%	Base 120%	Base 130%	Alt. 1 100%	Alt. 1 120%	Alt. 1 130%	Alt. 2 100%	Alt. 2 120%	Alt. 2 130%
Mean	9.67	10.43	10.92	0.01	0.02	0.03	0.47	0.62	0.71
Std. Deviation	0.86	0.73	0.88	0.03	0.04	0.05	0.19	0.21	0.26
Statistical Significance:									
Compared to base case same volume				100%	100%	100%	100%	100%	100%
Difference is Significant?				Yes	Yes	Yes	Yes	Yes	Yes
Compared to same case base volume		95%	100%		44%	71%		89%	97%
Difference is Significant?		Yes	Yes		No	No		No	Yes

**Table 7-5. Statistics for Average Queue Length**

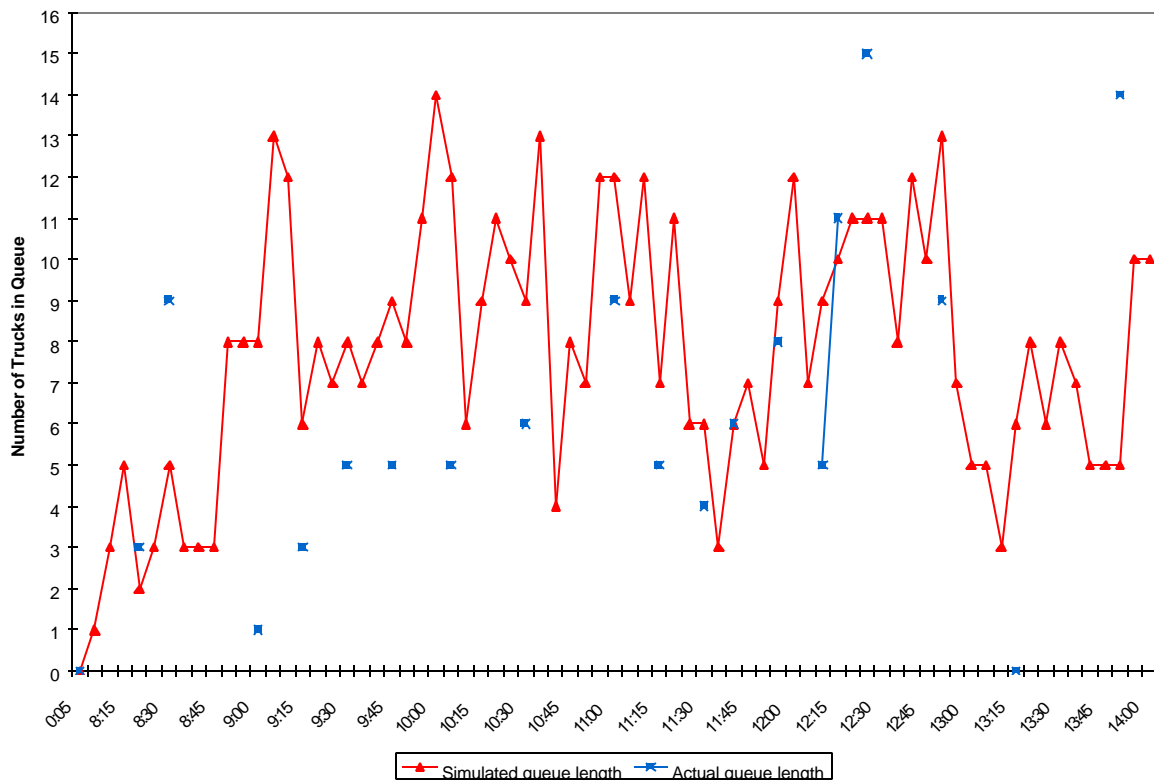




**Figure 7-5. Average Queue Length**

It is clear that the average queue length for the base case scenarios increased with the traffic arrival rate, and this is consistent with the average amount of time the scales were closed in section 7.1. The queue is practically non-existent in the first alternate scenario because the number of trucks weighed during the simulation is so small. The small increase in queue size with traffic volume is not statistically significant. The queue length for the second alternate scenario is less than one, somewhat greater than for the first alternate scenario, but still significantly less than the base case.

Figure 7-6 portrays the simulated queue length as a function of time for one iteration of the base case, and the actual queue length recorded periodically by SDDOT during six hours of station operation. While nothing can be proved or disproved by such a comparison, the simulated queue length appears to exhibit the same type of behavior and stay within the same bounds as the actual queue length observations.



**Figure 7-6. Comparison of Simulated to Actual Queue Length over Time**

## 7.6 Average Time to Transit Station

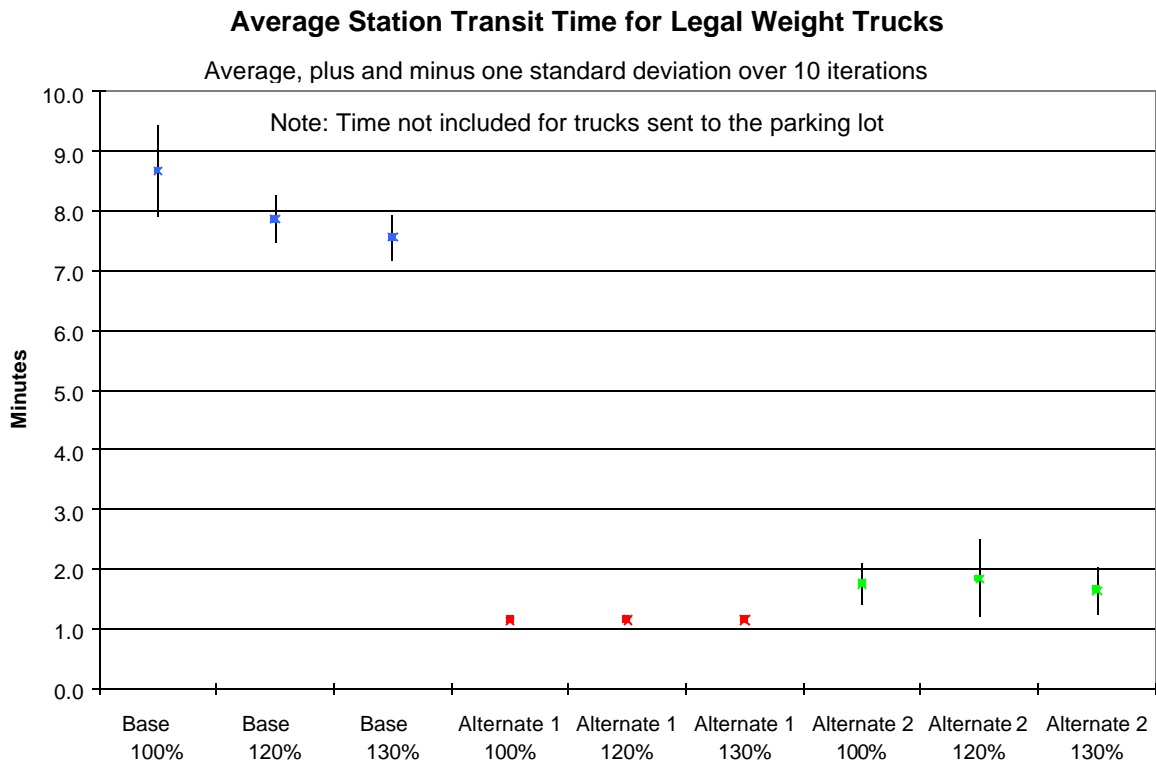
Table 7-6 and figure 7-7 show the average time to transit the station for trucks of legal weight that entered the station. Overweight trucks or trucks that were inspected because of safety or driver credential concerns were excluded because their longer times were not caused by waiting in line. The time to transit the station for each truck is the number of minutes from when it was created on an origin link to when it left the simulation on a destination link. The average time is the sum of a constant (the travel time with no delay) and a waiting time caused by queuing.

Within the base case, the average time went down slightly as the traffic level increased because the scales were closed more often and more trucks were waved past the scale without stopping. The lower time for those trucks lowered the average time.

The average waiting time for the first alternate scenario was significantly less than for the base case scenarios, and somewhat smaller than for the second alternate scenario. These results are consistent with the average queue lengths reported in section 7.4. Most trucks took the bypass lane without stopping, and the trucks that were weighed encountered short or non-existent queues at the scale.

Station transit time (min.)	Base	Base	Base	Alt. 1	Alt. 1	Alt. 1	Alt. 2	Alt. 2	Alt. 2
	100%	120%	130%	100%	120%	130%	100%	120%	130%
Mean	8.68	7.86	7.56	1.14	1.15	1.15	1.75	1.84	1.65
Std. Deviation	0.77	0.39	0.39	0.03	0.02	0.02	0.35	0.65	0.40
Statistical Significance:									
Compared to base case same volume				100%	100%	100%	100%	100%	100%
Difference is Significant?				Yes	Yes	Yes	Yes	Yes	Yes
Compared to same case base volume		99%	100%		45%	59%		28%	47%
Difference is Significant?		Yes	Yes		No	No		No	No

**Table 7-6. Statistics for Average Time to Transit Station**



**Figure 7-7. Average Time to Transit Station**

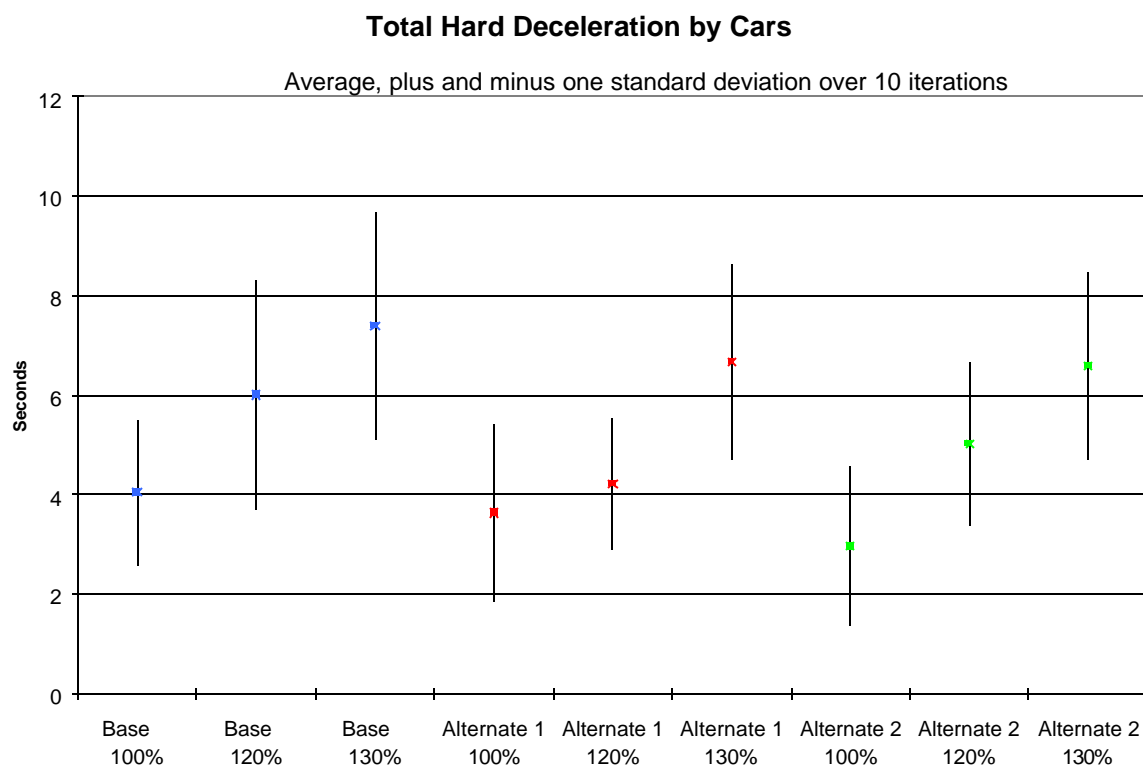
## 7.7 Average Hard Deceleration for Cars

Table 7-7 and figure 7-8 show the average number of seconds of hard deceleration for cars. As explained in section 2, Mitretek's threshold of hard deceleration for a car is 0.3g. In perfect driving conditions, hard deceleration would never be necessary. However, variations in driver attentiveness, reaction time, speed, and brake performance result in some cases where harder braking than average is necessary to avoid a collision. Westa does not try to predict collisions, but uses the measure of hard deceleration as a surrogate measure of safety. Hard braking for cars is typically caused by having to brake harder than expected to avoid hitting the truck slowing to enter the station and having to brake on the right lane of the highway approaching the spot where trucks exiting the station merge onto the

highway. Cars may shift to the left lane to avoid slowing down at this spot, but sometimes a lane shift is not possible.

Hard decel. for cars (sec.)	Base 100%	Base 120%	Base 130%	Alt. 1 100%	Alt. 1 120%	Alt. 1 130%	Alt. 2 100%	Alt. 2 120%	Alt. 2 130%
Mean	4.05	6.01	7.40	3.64	4.22	6.67	2.96	5.03	6.59
Std. Deviation	1.46	2.30	2.29	1.78	1.31	1.97	1.61	1.65	1.88
Statistical Significance:									
Compared to base case same volume				42%	95%	55%	87%	71%	60%
Difference is Significant?				No	Yes	No	No	No	No
Compared to same case base volume		96%	100%		58%	100%		99%	100%
Difference is Significant?		Yes	Yes		No	Yes		Yes	Yes

**Table 7-7. Statistics for Seconds of Hard Deceleration for Cars**



**Figure 7-8. Average Number of Seconds of Hard Braking for Cars**

All scenarios clearly experience greater levels of cars decelerating as the traffic level increases. As more trucks exit and reenter the highway, there is more friction with cars. However, there is no statistically significant difference among the scenarios with a given traffic level. That is to be expected since there is no difference in number of trucks exiting or reentering the highway among the three scenarios. All trucks exit the highway and then reenter the highway, whether they have been weighed or not.

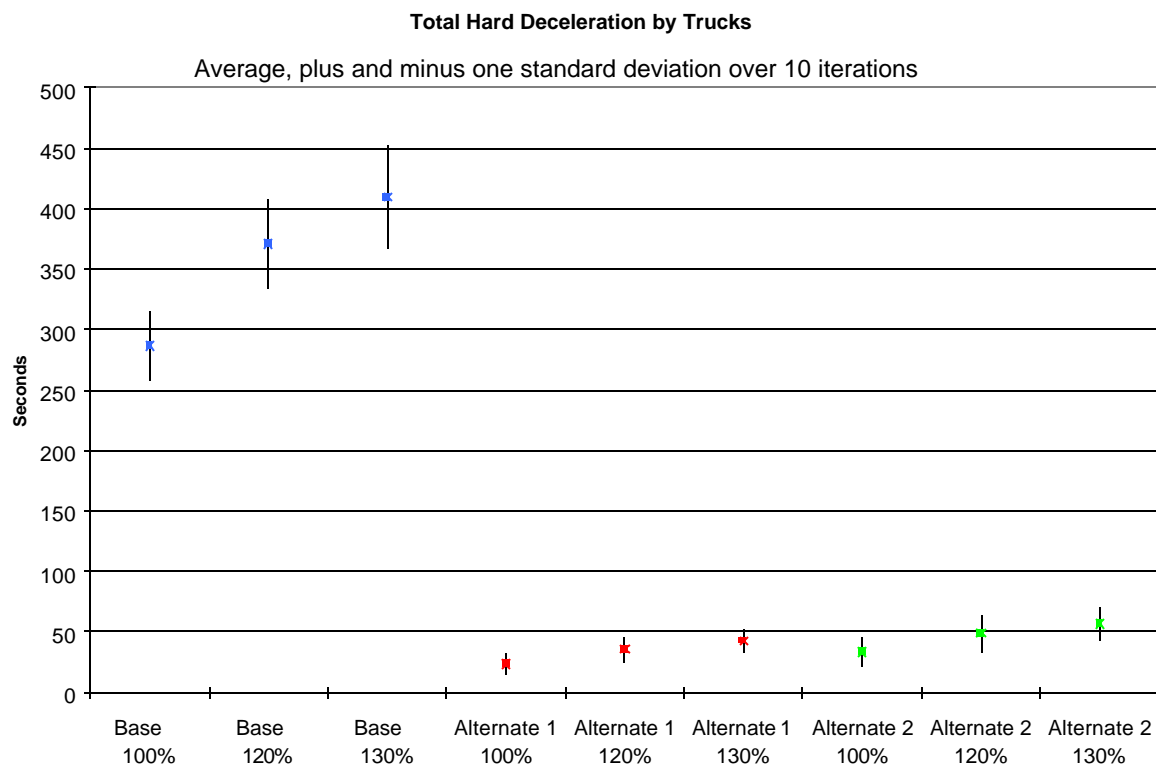
## 7.8 Average Hard Deceleration for Trucks

Table 7-8 and figure 7-9 show the average number of seconds of hard deceleration for trucks. Most of the deceleration comes on the exit ramp and as trucks reenter the highway. Mitretek's threshold of hard deceleration for a truck is 0.2g. For the base case scenario, the amount of hard deceleration increases with traffic volume. As the volume increases, the average truck queue length increases, and the tail end of the queue is encountered sooner by trucks entering the station.

For the first and second alternate scenarios, the queue of trucks is far shorter, and the trucks have much more time to slow gradually as they enter the station. For each of these cases, the increase caused by the increase in traffic is small but statistically significant because of the small standard deviations.

Hard decel. for trucks (sec.)	Base 100%	Base 120%	Base 130%	Alt. 1 100%	Alt. 1 120%	Alt. 1 130%	Alt. 2 100%	Alt. 2 120%	Alt. 2 130%
Mean	286.70	371.06	409.82	23.41	35.46	42.60	33.16	48.71	56.74
Std. Deviation	29.29	37.73	42.24	8.33	11.11	9.63	12.48	15.73	13.52
Statistical Significance:									
Compared to base case same volume				100%	100%	100%	100%	100%	100%
Difference is Significant?				Yes	Yes	Yes	Yes	Yes	Yes
Compared to same case base volume		100%	100%		99%	100%		98%	100%
Difference is Significant?		Yes	Yes		Yes	Yes		Yes	Yes

**Table 7-8. Statistics for Seconds of Hard Deceleration for Trucks**



**Figure 7-9. Average Number of Seconds of Hard Deceleration for Trucks**



## Section 8

# Results for Lehi Weigh Station

Mitretek ran ten iterations for each of the sixteen scenarios using a different random seeds for each iteration. Each iteration produced a summary file, from which the following values were extracted:

1. Number of trucks that were weighed
2. Number of trucks that remained on the highway, skipping the station altogether
3. Number of trucks that took the bypass lane within the station
4. Total time the queue for the static scales overflowed
5. Total time the station and the scales were closed because of overflow on the entrance ramp
6. Number of trucks waved past the static scale because of overflow on the entrance ramp
7. Average queue length for the static scale
8. Total seconds of hard deceleration (greater than 0.2g) for trucks on the station entrance ramp
9. Number of overweight trucks that were not caught
10. Number of trucks with safety or credential problems that were not caught
11. Number of trucks detained in the parking lot
12. Average time to transit the station

Each of these measures of effectiveness is described in a subsection below. The results are presented and graphed for each scenario. For each measure of effectiveness, a table presents the average value  $\Sigma x_i/10$  and the standard deviation  $\sqrt{(\Sigma x_i^2/10)}$ . The table then presents the statistical significance from two  $\chi^2$  (chi-square) tests. The first  $\chi^2$  test compares the results of ten iterations of an alternate configuration scenario against the ten iterations of the base case scenario with the same transponder percentage. The second  $\chi^2$  test compares the results for the ten iterations of a scenario with increased transponder percentage against the ten iterations of the same configuration but the base level of transponder percentage. Thus it is apparent which changes are due to the different station configuration and which changes are due to increased transponder percentages. If the level of significance is greater than 90% or 95%, there is high confidence that the alternate scenario does indeed make a difference to the average value of the measure of effectiveness. If the level of significance is less than 90%, it cannot be said that the alternative scenario has a different result than the base scenario.

Following each table, a plot shows the average value across the 10 iterations for each scenario. The averages for the four base case scenarios are black squares, the averages for the four scenarios with dual static scales are green squares, the averages for the scenarios with mainline WIM scale are red squares, and the averages for the scenarios with both dual static scales and a mainline WIM scale are blue squares. Each plot also features vertical bars indicating one standard deviation above and below the average for each scenario. If the standard deviation is large in relation to the difference between the average value for the base scenario and the average value for an alternate scenario, then the difference in the average value is not likely to be statistically significant. In general, the smaller the standard deviation, the more likely results are to have high values of statistical significance.

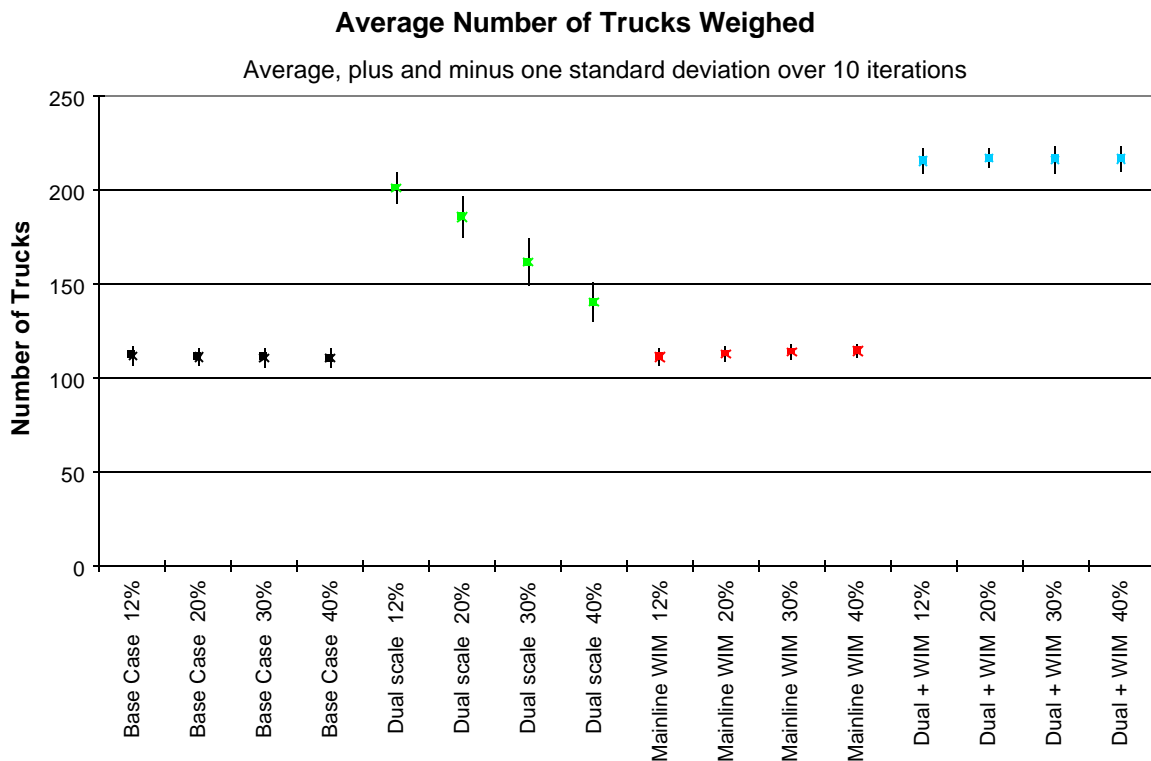
## 8.1 Average Number of Trucks Weighed

Table 8-1 and figure 8-1 show the average number of trucks weighed at the static scales for each scenario. For the base case and mainline WIM scale scenarios, this number did not change with transponder level. This fact indicates that the effective maximum number of trucks that could be

weighed had been reached even at the highest transponder level, and any additional truck traffic was spilled over as bypasses (see table 8-2 and figure 8-2). There were always enough trucks waiting to be weighed to keep the static scale busy.

Number of Trucks Weighed at the Static Scales								
% Transponders	Average				Standard Deviation			
	Base	Dual	WIM	Both	Base	Dual	WIM	Both
12%	111.8	201.1	110.8	215.4	5.6	8.7	4.8	6.6
20%	111.0	185.5	112.7	217.0	4.4	11.7	3.9	5.2
30%	110.7	161.4	113.7	216.2	5.1	12.4	3.9	7.4
40%	110.4	140.2	114.1	216.5	5.5	10.9	4.1	7.3
Statistical significance compared to base case with same transponder percent					Statistical significance compared to same configuration with 12% transponders			
12%	--	100.0%	32.8%	100.0%	--	--	--	--
20%	--	100.0%	62.7%	100.0%	27.4%	99.7%	65.5%	42.8%
30%	--	100.0%	84.2%	100.0%	34.9%	100.0%	84.4%	18.3%
40%	--	100.0%	89.5%	100.0%	42.2%	100.0%	88.3%	25.5%

**Table 8-1. Statistics for Number of Trucks Weighed**



**Figure 8-1. Average Number of Trucks Weighed**

The effective maximum number of trucks that can be weighed in an hour is a function of the average time to weigh a truck and the time between trucks from when one truck begins to leave the scale to



when the next truck is in place ready to be weighed. In the model these times were 47 seconds and 17 seconds, respectively. Thus the average service time was 64 seconds, for an average of 56 trucks weighed per hour. For the two-hour simulation, one could expect 112 trucks to be weighed, and that is very close to the figure observed for the base case and mainline WIM scale configurations.

For the dual scale scenarios, there was twice the capacity for weighing trucks. At base transponder level, the number of trucks weighed was almost twice the base level, indicating that the number of trucks needing to be weighed was almost double the number that a single scale could handle. As the percentage of trucks with transponders increased, the number of trucks needing to be weighed decreased, so that both scales were not used to full capacity. When the dual scales were underutilized, overweight trucks were seldom routed to the bypass lane.

For the scenario with both dual scales and mainline WIM scale, the number of trucks weighed was a constant value, twice the value as for a single scale. This fact indicates that both scales were kept busy continually, weighing approximately 56 trucks per hour each. There were more trucks to be weighed for these scenarios than for the dual scale scenarios because overweight trucks with transponders were not permitted to bypass the station.

In all cases, the standard deviation was very small. No matter what the random number seed, the scales were kept busy to the same extent for each iteration of a given scenario.

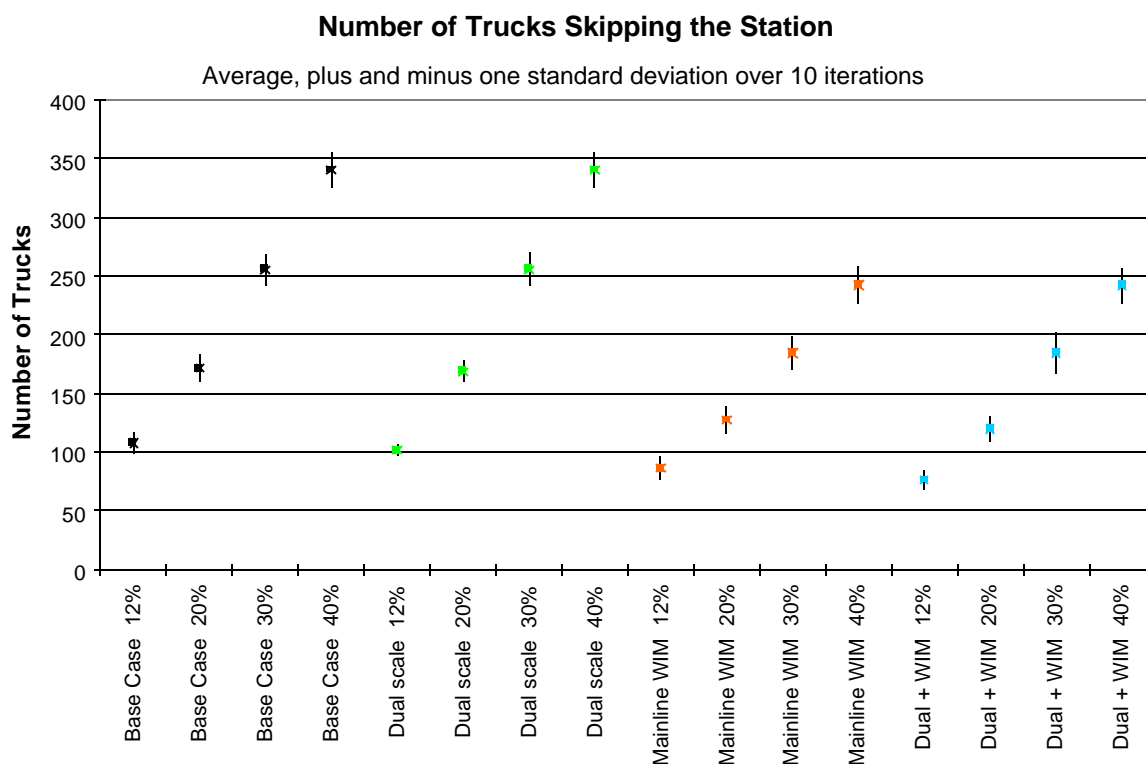
## 8.2 Average Number of Trucks Skipping the Station

Table 8-2 and figure 8-2 show the average number of trucks that remained on the highway, skipping the station altogether. For the base case scenarios and the dual scale scenarios, this is primarily the number of trucks with transponders. For the scenarios with a mainline WIM scale, only trucks with transponders and which did not exceed maximum axle weight were permitted to remain on the highway. For all scenarios, a small number trucks may skip the station during periods the station is closed because of queue overflow on the entrance ramp.

Clearly, the number of trucks skipping the station increases with the percentage of transponder equipage. The figures for the dual scale scenarios match the figures for the base case scenarios because the number of trucks permitted to remain on the highway does not differ between the two sets of scenarios. The scenarios with a mainline WIM scale have fewer such trucks; the difference is the number of trucks with transponders, but which are over maximum axle weight.

Number of Trucks Remaining on the Highway, Skipping the Station								
% Transponders	Average				Standard Deviation			
	Base	Dual	WIM	Both	Base	Dual	WIM	Both
12%	107.4	101.7	85.9	76.4	9.3	5.0	9.8	8.0
20%	171.4	168.5	127.4	119.9	12.4	9.3	11.9	10.6
30%	255.6	255.7	184.2	184.4	14.0	14.0	14.9	18.6
40%	340.5	340.6	242.2	242.0	15.2	15.2	16.1	15.6
	Statistical significance compared to base case with same transponder percent				Statistical significance compared to same configuration with 12% transponders			
12%	--	89.5%	100.0%	100.0%	--	--	--	--
20%	--	43.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
30%	--	1.3%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
40%	--	1.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

**Table 8-2. Statistics for Number of Trucks Skipping the Station**



**Figure 8-2. Average Number of Trucks Skipping the Station**

### 8.3 Average Number of Trucks Bypassing the Static Scales Within the Station

Table 8-3 and figure 8-3 show the average number of trucks that bypassed the static scale within the station for each scenario. For all scenarios, this is the number of trucks that were directed to the bypass lane by the low-speed WIM scale on the station entrance ramp, plus the number of trucks that spilled over onto the bypass lane because the queue of trucks waiting for the static scale overflowed. The process of spilling trucks onto the bypass lane within the station is the “escape valve” for dealing with the situation where the number of trucks waiting to be weighed temporarily exceeds the holding capacity of the ramp to the static scales.

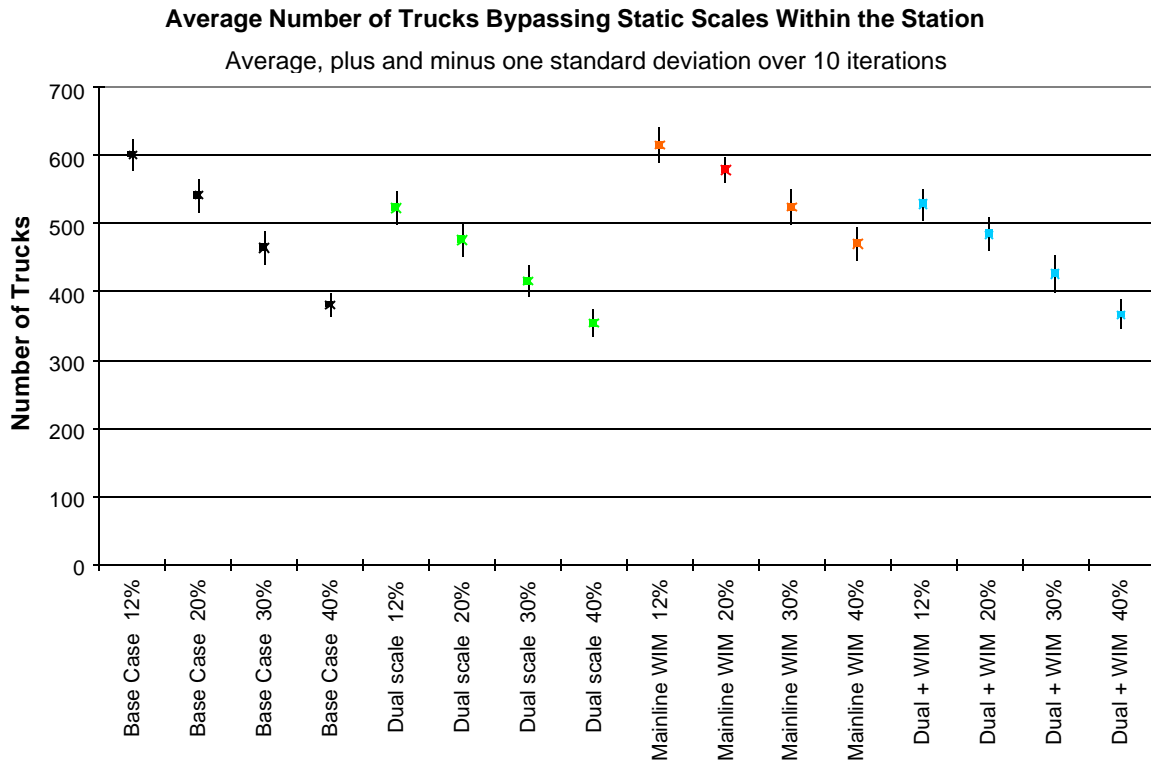
For all scenarios, this number decreased as the percentage of trucks with transponders increased. Each truck with a transponder that did not enter the station was one less truck to traverse the bypass lane in the station. Essentially figure 8-3 and figure 8-2 are mirror images of each other. The figures for the two sets of scenarios with dual scales are lower than those without; since more trucks could be weighed on the dual scales, there were fewer overflows to the bypass lane. The figures for the mainline WIM scale scenarios are higher than those for the base case configuration because more trucks must enter the station.

The figures for the scenarios with both dual scales and mainline WIM scale are the same as those for the dual scales only, because the second scale eliminates the overflow to the bypass lane. The only

trucks on the bypass lane are the trucks without transponders that do not exceed maximum axle weight, and the number of these trucks is the same for both configurations.

Number of Trucks Bypassing the Static Scales Within the Station								
% Transponders	Average				Standard Deviation			
	Base	Dual	WIM	Both	Base	Dual	WIM	Both
12%	601.2	522.6	614.8	528.3	23.2	23.9	26.3	23.3
20%	541.6	475.8	578.6	484.0	24.8	24.9	18.6	24.8
30%	465.0	415.9	524.4	426.4	24.8	23.9	26.1	28.2
40%	381.0	353.9	470.6	366.5	18.3	19.6	24.6	22.2
Statistical significance compared to base case with same transponder percent					Statistical significance compared to same configuration with 12% transponders			
12%	--	100.0%	76.4%	100.0%	--	--	--	--
20%	--	100.0%	99.9%	100.0%	100.0%	100.0%	99.8%	99.9%
30%	--	100.0%	100.0%	99.4%	100.0%	100.0%	100.0%	100.0%
40%	--	99.5%	100.0%	87.2%	100.0%	100.0%	100.0%	100.0%

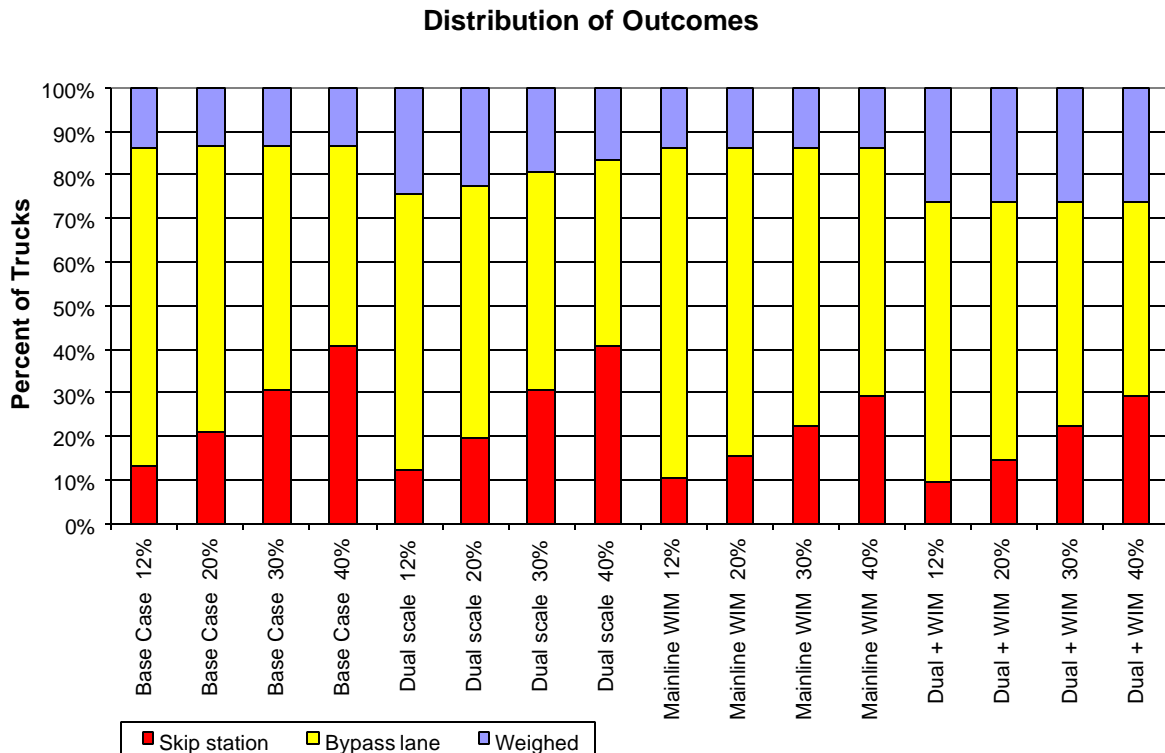
**Table 8-3. Statistics for Number of Trucks Bypassing the Static Scales Within the Station**



**Figure 8-3. Average Number of Trucks Bypassing Static Scales Within the Station**

Figure 8-4 shows a composite of the three previous figures. It shows the percentage of trucks that were weighed, skipped the station, or bypassed the static scales within the station. The number of trucks that skipped the station (the bottom section of the bars) is determined by the transponder

percentage and the presence or absence of mainline WIM scales. The number of trucks to be weighed (the top section of the bars) is determined by the minimum of the scale capacity (single or dual scale) and the number of trucks over maximum axle weight. The number of trucks taking the bypass lane (the center section of the bars) is the number of trucks under maximum axle weight plus the number of trucks that overflowed to the bypass lane when the line to the static scale was too full. It is the latter group of trucks that grows or shrinks depending on the capacity of the scales to handle the number of trucks that should be weighed.



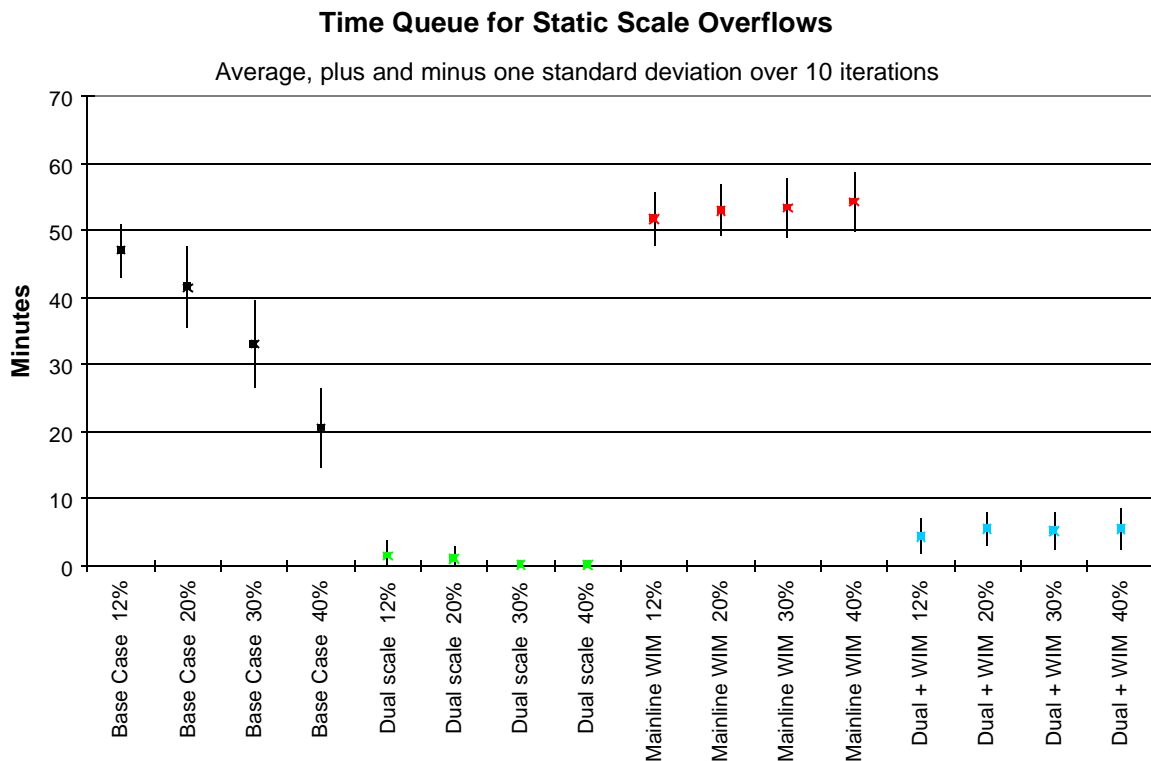
**Figure 8-4. Proportion of Trucks on Static Scales, Bypass Lane, and Mainline Highway**

#### 8.4 Average Time the Queue for the Static Scale Overflows

Table 8-4 and figure 8-5 present the average time (in minutes) the queue for the static scale backed up to the point where all trucks entering the station were directed to the bypass lane. The total simulation length was two hours.

Number of Minutes the Queue for the Static Scale Overflowed								
% Transponders	Average				Standard Deviation			
	Base	Dual	WIM	Both	Base	Dual	WIM	Both
12%	47.0	1.4	51.6	4.3	4.1	2.4	4.1	2.7
20%	41.5	1.0	52.9	5.5	6.1	2.0	3.8	2.5
30%	33.0	0.0	53.3	5.1	6.5	0.2	4.5	3.0
40%	20.5	0.0	54.2	5.4	5.9	0.0	4.4	3.1
Statistical significance compared to base case with same transponder percent					Statistical significance compared to same configuration with 12% transponders			
12%	--	100.0%	97.9%	100.0%	--	--	--	--
20%	--	100.0%	100.0%	100.0%	97.1%	34.9%	52.0%	67.5%
30%	--	100.0%	100.0%	100.0%	100.0%	91.6%	61.5%	46.4%
40%	--	100.0%	100.0%	100.0%	100.0%	92.6%	81.2%	60.1%

**Table 8-4. Statistics for Number of Minutes Queue for Static Scale Overflows**



**Figure 8-5. Average Number of Minutes Queue for Static Scale Overflows**

For the base case scenarios, this figure decreased as the transponder percentage increased, because fewer overweight trucks entered the station, and fewer such trucks had to wait in line to be weighed. For the dual scale scenarios, the doubled scale capacity was enough to weigh all the trucks over maximum axle weight, so an overflowing queue situation did not develop. For the mainline WIM scale scenarios, the queue overflow situation happened most frequently because more trucks over maximum weight were entering the station. The different number of trucks with transponders did not affect the queue length because the same number of trucks over maximum axle weight (all of them) were

directed toward the static scales. The fourth configuration, with both dual scales and mainline WIM scale, had a small amount of queue overflow because the number of overweight trucks with transponders, added to the number of overweight trucks without transponders, exceeded the capacity of the dual scales.

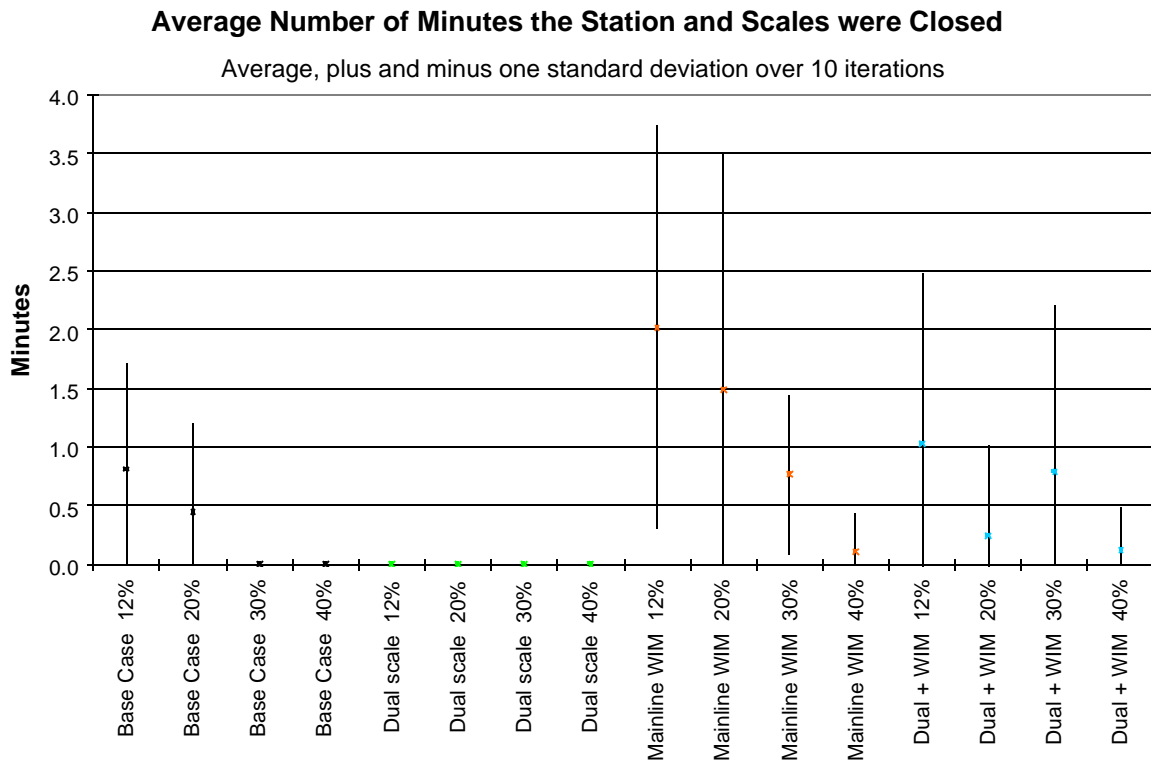
## 8.5 Average Time Station and Scales Were Closed

According to current operating policy at the Lehi station, if the queue of trucks on the station entrance ramp backs up to the highway, the station closes, trucks approaching the station may remain on the highway, and trucks already in queue for the static scale are waved by the scales without stopping. The only time this happens is when there is a stop or significant slowdown on the bypass lane within the station, causing a backup on the entrance ramp. A truck could stop on the bypass lane because the station operator spots an apparent safety violation or has reason to check the driver's credentials, and directs the truck to the parking lot for inspection.

Table 8-5 and figure 8-6 present the average time (in minutes) the station was closed because of queue backup on the entrance ramp. The total amount of time represented by the simulation was two hours. The key input values driving this result were the arrival rate of trucks, the percentage of trucks with transponders not required to enter the station, and the average time to weigh a truck. AHTD has confirmed that the results for several iterations of the base case are consistent with their experience.

Number of Minutes the Station and Scales were Closed								
% Transponders	Average				Standard Deviation			
	Base	Dual	WIM	Both	Base	Dual	WIM	Both
12%	0.81	0.00	2.02	1.03	0.91	0.00	1.72	1.45
20%	0.45	0.00	1.49	0.24	0.76	0.00	2.01	0.77
30%	0.00	0.00	0.76	0.79	0.00	0.00	0.68	1.42
40%	0.00	0.00	0.11	0.12	0.00	0.00	0.34	0.37
Statistical significance compared to base case with same transponder percent					Statistical significance compared to same configuration with 12% transponders			
12%	--	98.9%	93.4%	29.8%	--	--	--	--
20%	--	92.3%	85.6%	44.5%	65.4%	--	46.5%	84.5%
30%	--	--	99.8%	90.4%	98.9%	--	95.4%	26.7%
40%	--	--	66.9%	66.9%	98.9%	--	99.7%	92.7%

**Table 8-5. Statistics for the Number of Minutes the Station and Scales were Closed**



**Figure 8-6. Average Number of Minutes Station and Scales were Closed**

The figures for the scenarios are consistent with the results of the previous section (times the queue to the static scale overflowed). For the base case scenarios, this figure decreased to zero as the transponder percentage increased, because fewer overweight trucks entered the station, and there were fewer occasions for backup on the bypass lane. For the dual scale scenarios, the doubled scale capacity was enough to weigh all the overweight trucks, so an overflowing queue situation did not develop and there were fewer trucks on the bypass lane to cause a slowdown. For the mainline WIM scale scenarios, the entrance ramp overflow situation happened most frequently because more overweight trucks were entering the station. The fourth configuration, with both dual scales and mainline WIM scale, had a smaller amount of ramp overflow than the mainline WIM scale scenario because the dual scale increased the weighing capacity, but more than the dual scale scenarios because the number of overweight trucks with transponders, added to the number of overweight trucks without transponders, exceeded the capacity of the dual scales. The standard deviations across the iterations are high because backup up on the bypass is a highly random event. It occurs occasionally, just like the real world situation.

## 8.6 Average Number of Trucks Waved Past the Static Scales

Whenever the station closes because of backup on the station entrance ramp, trucks in line for the static scales are waved past the scales without stopping. Table 8-6 and figure 8-7 present the average number of such trucks. The figures are clearly highly correlated with the figures of table 8-5 and figure 8-6, since trucks are waved past the static only when the station is closed. The standard deviations across the iterations are high because station closing is a highly random event.

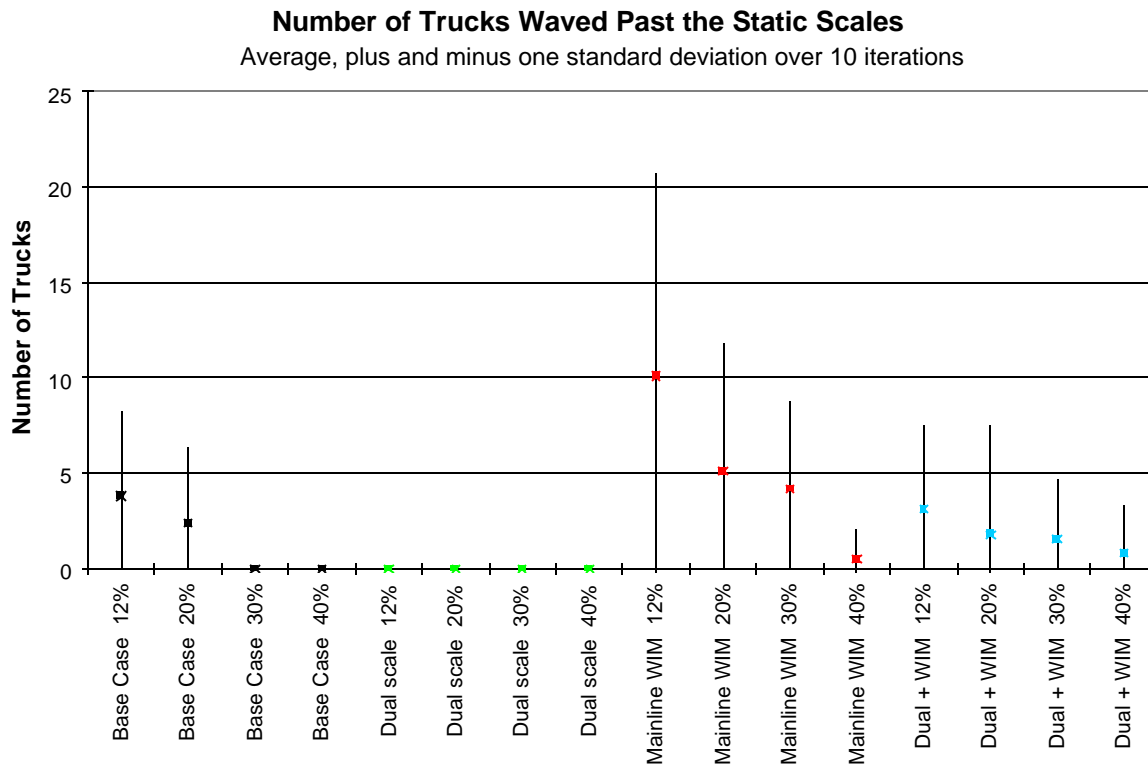
Number of Trucks Waved Past Static Scale Because of Overflow								
% Transponders	Average				Standard Deviation			
	Base	Dual	WIM	Both	Base	Dual	WIM	Both
12%	3.8	0.0	10.1	3.1	4.4	0.0	10.6	4.4
20%	2.4	0.0	5.1	1.8	4.0	0.0	6.8	5.7
30%	0.0	0.0	4.2	1.6	0.0	0.0	4.6	3.1
40%	0.0	0.0	0.5	0.8	0.0	0.0	1.6	2.5
	Statistical significance compared to base case with same transponder percent				Statistical significance compared to same configuration with 12% transponders			
12%	--	98.6%	89.9%	26.1%	--	--	--	--
20%	--	92.8%	70.8%	21.2%	53.3%	--	77.4%	41.5%
30%	--	--	99.0%	86.7%	98.6%	--	87.5%	60.0%
40%	--	--	66.9%	66.9%	98.6%	--	98.9%	82.7%

**Table 8-6. Statistics for Number of Trucks Waved Past the Static Scales**

### 8.7 Average Queue Length

Table 8-7 and figure 8-8 show the average queue length over the course of the simulated two hours. This statistic includes the count of all trucks on links within the station up to the static scale or both static scales. During the simulation the queue could be in any of the following states: (a) maximum value when trucks nearly reach the entrance to the ramp on the highway, causing the station to close, (b) decreasing in size quickly as trucks pass by the closed scale without stopping, at a rate faster than new trucks arrive, (c) decreasing in size slowly as trucks are weighed at the scale at a rate faster than new trucks arrive, and (d) growing, as trucks leave the queue to be weighed, but trucks arrive from the highway at a faster rate than they can be weighed. Most of the time, the queue did not extend back to the highway and the scales did not close. The number of trucks that fit on each link is not constant because of the variations in truck length, but it doesn't change much.

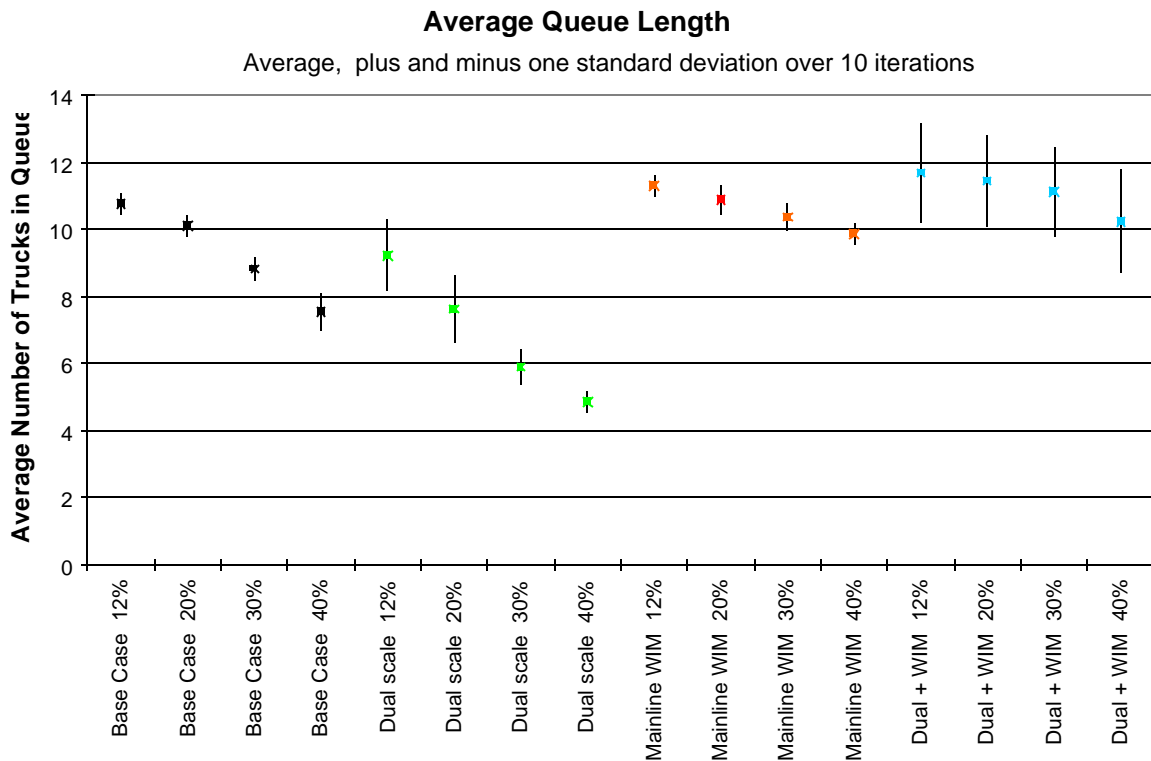




**Figure 8-7. Average Number of Trucks Waved Past the Static Scales**

Average Queue Length								
% Transponders	Average				Standard Deviation			
	Base	Dual	WIM	Both	Base	Dual	WIM	Both
12%	10.75	9.21	11.29	11.68	0.32	1.08	0.31	1.51
20%	10.10	7.61	10.87	11.44	0.34	1.00	0.42	1.38
30%	8.82	5.88	10.35	11.11	0.38	0.53	0.40	1.36
40%	7.53	4.84	9.85	10.22	0.56	0.35	0.35	1.55
	Statistical significance compared to base case with same transponder percent				Statistical significance compared to same configuration with 12% transponders			
12%	--	100.0%	99.9%	92.5%	--	--	--	--
20%	--	100.0%	100.0%	99.2%	100.0%	99.7%	97.8%	27.5%
30%	--	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	58.5%
40%	--	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	94.6%

**Table 8-7. Statistics for Average Queue Length**



**Figure 8-8. Average Queue Length**

It is evident that the average queue length is correlated to the number of trucks entering the station and the average number of trucks bypassing the static scales. As the percentage of trucks with transponder increased, fewer trucks entered the station and the queue was shorter. The mainline WIM scale caused more trucks to enter the station, so the queue was longer. For the dual scale scenarios, the dual scales were able to dispose of the queue more quickly, so queue lengths were shorter.

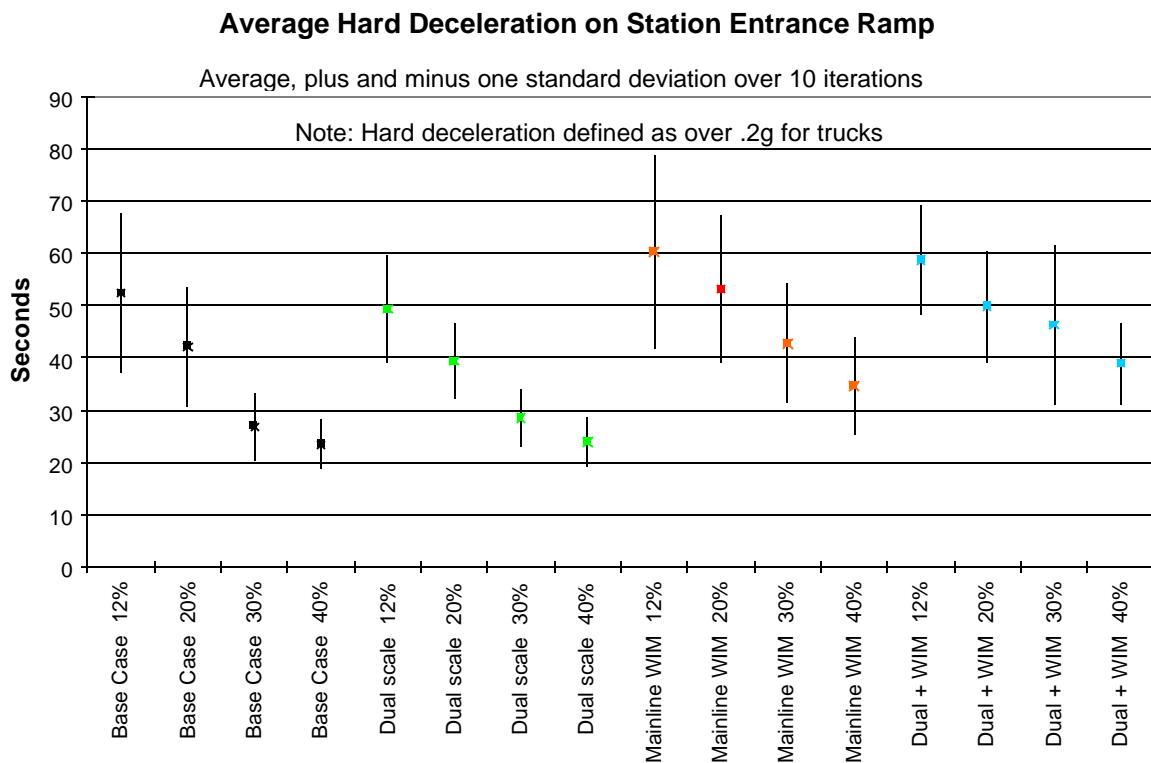
### 8.8 Average Hard Deceleration for Trucks on the Station Entrance Ramp

Table 8-8 and figure 8-9 show the average number of seconds of hard deceleration for trucks on the station entrance ramp. Mitretek's threshold of hard deceleration for a truck is 0.2g. When a truck exceeds this deceleration threshold, it is braking at a harder than comfortable rate to avoid hitting the truck at the tail end of the queue.

For all configurations, the amount of hard deceleration decreased with increasing transponder percentage. This decrease was an effect of the shorter queue lengths (see the previous subsection). When queues are shorter, there is more distance for a truck to stop between the beginning of the station entrance ramp and the tail end of the queue of trucks, so there is less need for sudden deceleration. The reduction in sudden decelerations in turn points to a decrease to the risk of a truck collision at the weigh station.

Seconds of Hard Deceleration on Station Entrance Ramp								
% Transponders	Average				Standard Deviation			
	Base	Dual	WIM	Both	Base	Dual	WIM	Both
12%	52.44	49.30	60.32	58.71	15.37	10.41	18.48	10.67
20%	42.14	39.36	53.18	49.80	11.46	7.37	14.34	10.86
30%	26.80	28.40	42.74	46.36	6.48	5.52	11.59	15.43
40%	23.38	23.80	34.54	38.90	4.79	4.70	9.36	7.94
	Statistical significance compared to base case with same transponder percent				Statistical significance compared to same configuration with 12% transponders			
12%	--	40.1%	68.6%	67.9%	--	--	--	--
20%	--	47.3%	92.7%	85.8%	89.3%	97.6%	65.3%	91.1%
30%	--	44.0%	99.9%	99.8%	100.0%	100.0%	98.0%	93.4%
40%	--	15.5%	99.6%	100.0%	100.0%	100.0%	99.9%	100.0%

**Table 8-8. Statistics for Seconds of Hard Deceleration on Station Entrance Ramp**



**Figure 8-9. Average Number of Seconds of Hard Deceleration on Station Entrance Ramp**

## 8.9 Average Number of Overweight Trucks Missed

Table 8-9 and figure 8-10 present the number of trucks that were over 80,000 pounds gross weight and were not apprehended or cited. There are three possibilities for how an overweight truck could escape enforcement. The first is that a truck over the gross weight may not exceed the maximum axle weight. Data collected by the Crittenden County WIM site revealed that approximately 6 % of the trucks over gross weight are not over axle weight. These trucks would be directed by the low-speed or mainline WIM scales to bypass the static scales, regardless of station overflow condition. The second possibility is that the overweight truck is spilled onto the bypass lane because the queue for the static scale overflowed. The third possibility is that the truck was in line for the static scale, but got waved past the scale because of queue overflow on the station entrance ramp.

Number of Overweight Trucks Missed								
% Transponders	Average				Standard Deviation			
	Base	Dual	WIM	Both	Base	Dual	WIM	Both
12%	32.0	14.5	26.4	5.1	5.8	2.4	5.4	2.0
20%	35.2	20.6	25.7	6.2	5.8	3.4	5.1	2.7
30%	38.0	29.5	25.2	8.0	4.8	4.6	4.5	2.4
40%	44.2	38.0	25.6	7.0	6.1	5.1	5.2	2.2
	Statistical significance compared to base case with same transponder percent				Statistical significance compared to same configuration with 12% transponders			
12%	--	100.0%	96.1%	100.0%	--	--	--	--
20%	--	100.0%	99.9%	100.0%	76.5%	100.0%	23.2%	67.1%
30%	--	99.9%	100.0%	100.0%	97.8%	100.0%	40.5%	98.7%
40%	--	97.6%	100.0%	100.0%	100.0%	100.0%	26.1%	93.3%

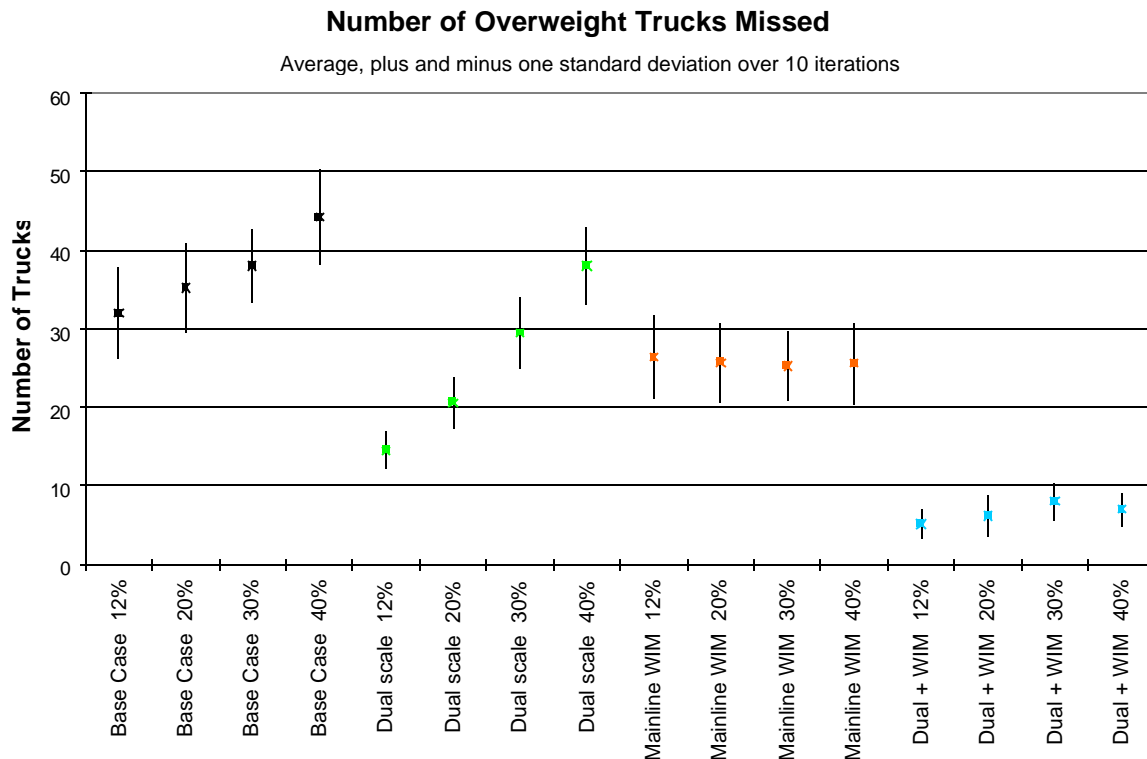
**Table 8-9. Statistics for Number of Overweight Trucks Missed**

For the base case and dual scale configurations, the number of overweight trucks missed increased when the transponder percent increased because overweight trucks with transponders were permitted to bypass the station. The dual scale scenarios missed fewer overweight trucks than the base case scenarios because there was no queue overflow, and no overweight trucks spilled over onto the bypass lane. The number of missed overweight trucks did not change with transponder percent for the configurations with mainline WIM scale because all trucks over maximum axle weight were directed into the station whether or not they had a transponder. The configuration with both dual scale and mainline WIM scale had the lowest number of missed overweight trucks because over axle weight trucks did not bypass the station and the queues to the static scales did not overflow to the bypass lane.

## 8.10 Average Number of Trucks Missed with Safety or Credentials Problems

Table 8-10 and figure 8-11 present the number of trucks with safety violations or credentials violations that were not caught. There are four possibilities for how such a truck could escape enforcement. The first is that such a truck may have a transponder (base case or dual scale configurations) or be under maximum axle weight and have a transponder (mainline WIM scale configurations) and therefore bypass the station. The second possibility is that such a truck is overweight but is spilled onto the bypass lane because the queue for the static scale overflowed. The third possibility is that such a truck

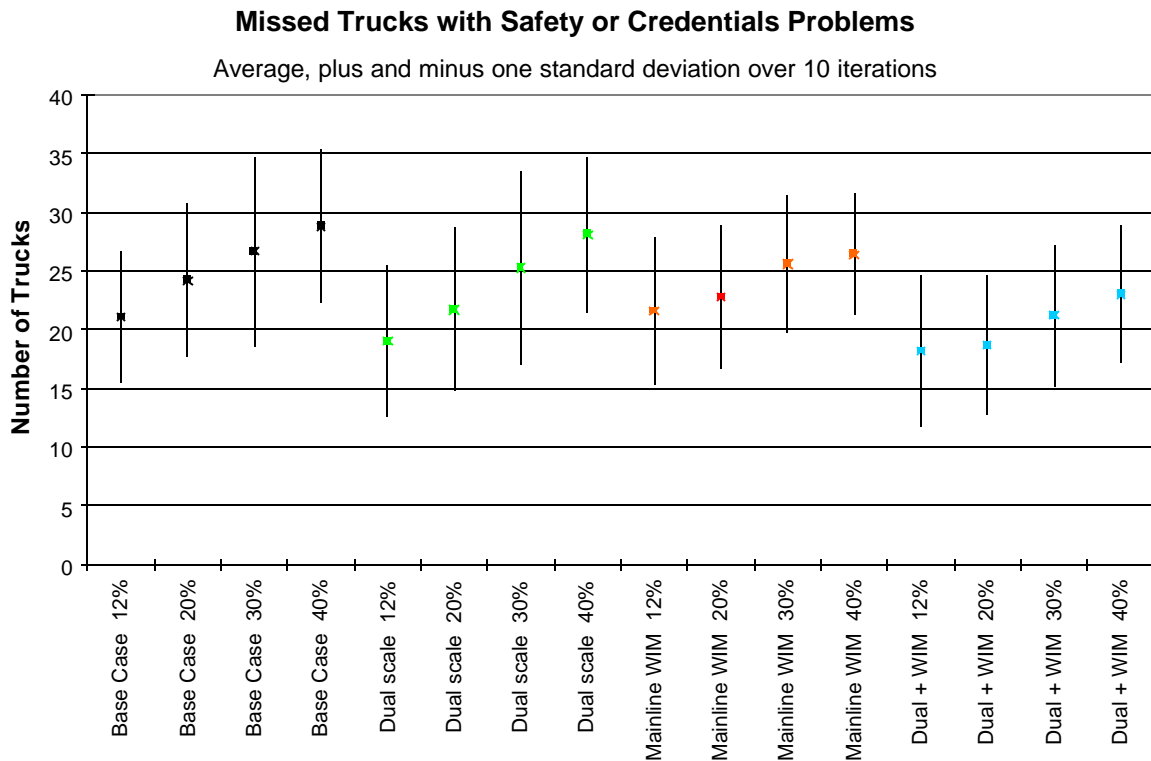
is overweight and was in line for the static scale, but got waved past the scale because of queue overflow on the station entrance ramp. The fourth possibility is that such a truck is not overweight and was directed to the bypass lane by the low-speed WIM scale and was not spotted by the station operator.



**Figure 8-10. Average Number of Overweight Trucks Missed**

Number of Trucks with Safety or Credential Problems that were Missed								
% Transponders	Average				Standard Deviation			
	Base	Dual	WIM	Both	Base	Dual	WIM	Both
12%	21.10	19.00	21.60	18.22	5.69	6.46	6.28	6.48
20%	24.20	21.70	22.80	18.70	6.55	6.98	6.16	5.93
30%	26.70	25.30	25.60	21.22	8.08	8.26	5.85	6.04
40%	28.80	28.10	26.40	23.00	6.58	6.67	5.21	5.89
	Statistical significance compared to base case with same transponder percent				Statistical significance compared to same configuration with 12% transponders			
12%	--	55.0%	14.6%	68.3%	--	--	--	--
20%	--	58.1%	37.2%	93.6%	72.7%	61.9%	32.9%	13.1%
30%	--	29.4%	26.9%	88.4%	91.0%	92.6%	84.2%	67.5%
40%	--	18.4%	62.2%	94.8%	98.8%	99.4%	92.1%	89.0%

**Table 8-10. Statistics for Number of Missed Trucks with Safety or Credentials Problems**



**Figure 8-11. Average Number of Missed Trucks with Safety or Credentials Problem**

For all configurations, the number of missed trucks with safety or credentials problems increased with increase transponder percentage because of the first possibility described above. The scenarios with dual scales had slightly fewer misses than the scenarios without dual scales because dual scales decreased the number of problem trucks overflowing to the bypass lane (the second and third possibilities described above). The fourth possibility described above is not affected by the configuration, so it causes no difference among the configurations. In general, the difference between configurations did not result in significant differences between results for this measure.

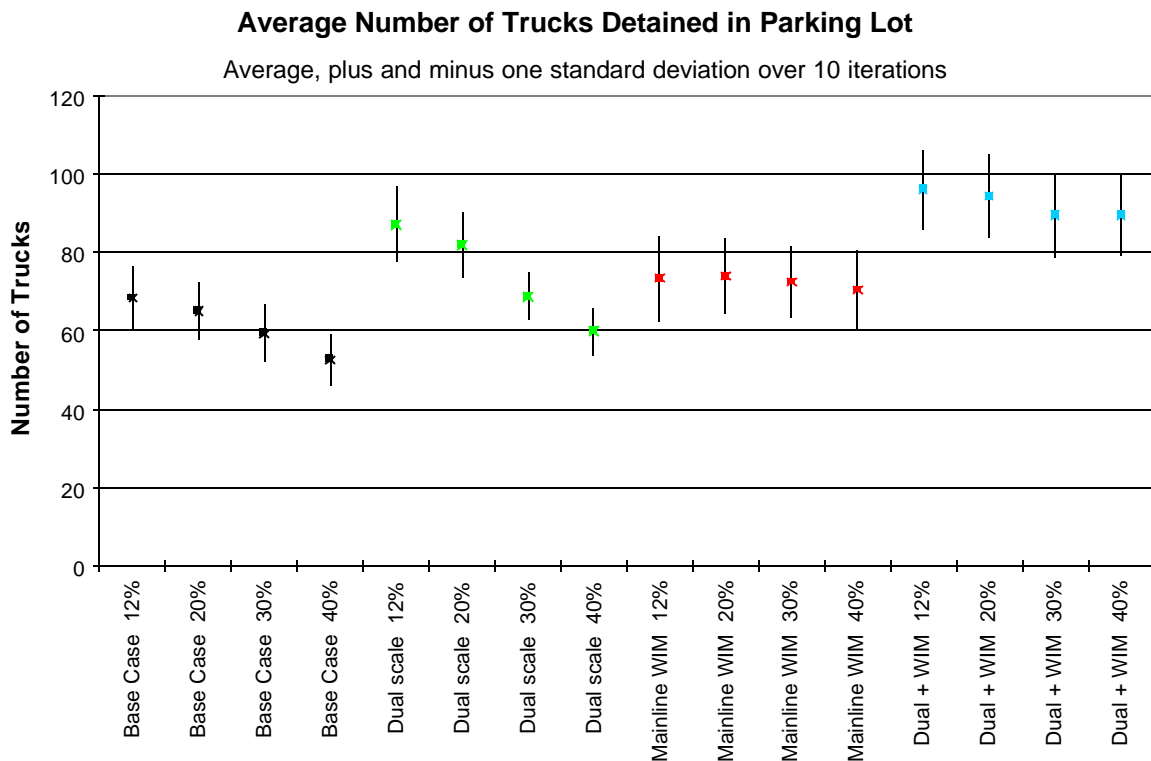
### 8.11 Average Number of Trucks Detained in Parking Lot

Table 8-11 and figure 8-12 show the average number of trucks detained in the parking lot. This figure includes overweight trucks being issued a citation or undergoing a permit check, trucks with a suspected safety violation being inspected, and trucks with suspected credentials violations undergoing a credentials or logbook check.

The number of trucks detained is a measure of the effectiveness of the station. It strongly correlates to the number of trucks weighed (discussed in section 8.1) because a truck can't be sent to the parking lot unless it passes over the scales and is directed to the lot by the station operator. For the base case and the dual scales scenarios, the number sent to the parking lot decreases as transponder percent increases because fewer overweight trucks pass the scales. For the scenarios with mainline WIM scales, the number of trucks over maximum axle weight that are sent to the scales does not change with transponder percentage.

Number of Trucks Detained in the Parking Lot								
% Transponders	Average				Standard Deviation			
	Base	Dual	WIM	Both	Base	Dual	WIM	Both
12%	68.4	87.1	73.4	96.1	8.3	9.8	11.0	10.3
20%	65.0	81.9	74.0	94.4	7.3	8.4	9.7	10.6
30%	59.3	68.7	72.5	89.6	7.4	6.2	9.1	10.7
40%	52.6	59.9	70.5	89.5	6.8	6.2	10.1	10.6
Statistical significance compared to base case with same transponder percent					Statistical significance compared to same configuration with 12% transponders			
12%	--	100.0%	73.3%	100.0%	--	--	--	--
20%	--	100.0%	97.0%	100.0%	65.7%	78.1%	10.2%	27.4%
30%	--	99.3%	99.8%	100.0%	98.1%	100.0%	15.6%	79.6%
40%	--	97.9%	100.0%	100.0%	100.0%	100.0%	45.3%	81.3%

**Table 8-11. Statistics for Number of Trucks Detained in the Parking Lot**



**Figure 8-12. Average Number of Trucks Detained in the Parking Lot**

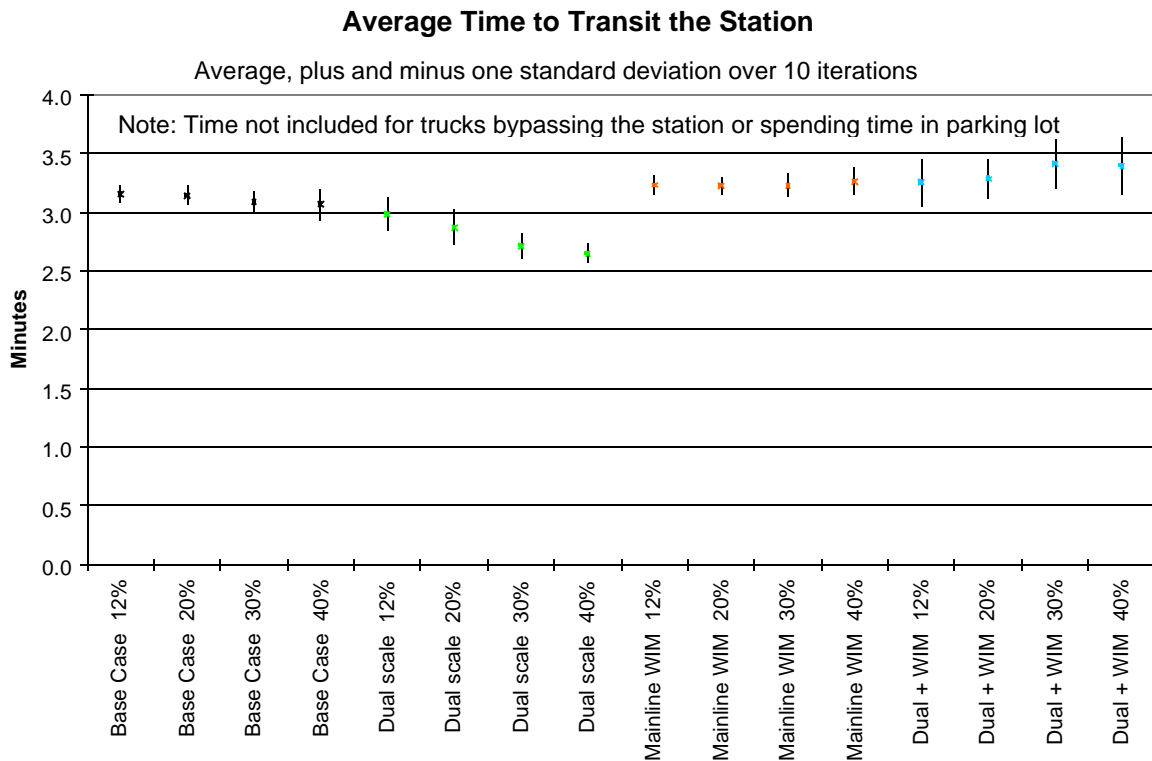
## 8.12 Average Time to Transit Station

Table 8-12 and figure 8-13 show the average time to transit the station for trucks of legal weight that entered the station. Overweight trucks or trucks that were inspected because of safety or driver credential concerns were excluded because their longer times were not caused by waiting in line. The time to transit the station for each truck is the number of minutes from when it was created on an

origin link to when it left the simulation on a destination link. The average time is the sum of a constant (the travel time with no delay) and a waiting time proportional to the average queue length.

Average Time (Minutes) for Trucks to Transit Station								
% Transponders	Average				Standard Deviation			
	Base	Dual	WIM	Both	Base	Dual	WIM	Both
12%	3.15	2.99	3.23	3.25	0.08	0.14	0.08	0.20
20%	3.14	2.87	3.23	3.29	0.08	0.15	0.07	0.18
30%	3.09	2.71	3.23	3.41	0.09	0.11	0.10	0.21
40%	3.07	2.65	3.26	3.39	0.14	0.08	0.12	0.24
Statistical significance compared to base case with same transponder percent					Statistical significance compared to same configuration with 12% transponders			
12%	--	99.6%	96.5%	84.2%	--	--	--	--
20%	--	100.0%	97.7%	96.7%	19.2%	90.2%	3.5%	29.4%
30%	--	100.0%	99.5%	100.0%	87.7%	100.0%	3.6%	88.4%
40%	--	100.0%	99.6%	99.8%	89.0%	100.0%	49.5%	81.2%

**Table 8-12. Statistics for Average Time to Transit Station**



**Figure 8-13. Average Time to Transit Station**

Time to transit the station correlates with average queue length reported in section 8.7. For the dual scales scenarios, however, it should be noted that the reported queue length is the sum of the queue



lengths for both scales, whereas a truck will have to wait in one queue, once it gets past the place where the two queues divide.

## Section 9

# Observations and Conclusions

### 9.1 Seymour Weigh Station

This section presents observations and conclusions about the base scenario for the Seymour weigh station and for the alternate scenarios in comparison to the base scenario.

#### 9.1.1 Results for Base Traffic Load Scenarios

The measures of effectiveness for the base case scenario confirm significant congestion at the Seymour weigh station. The high arrival rate relative to the average rate for weighing a truck ensures that the queue on the entrance ramp will fill up frequently, causing frequent station closings.

The two scenarios with longer ramps do not produce significant improvements to any measures of effectiveness except hard deceleration on the station entrance ramp. It is true that the ramps take longer to fill up, but the ramps also take longer to empty once they are full, so there is little net reduction to station closing time. Moreover, since the queues are longer on the longer ramps, the time spent waiting in line by trucks is significantly greater.

The measures of effectiveness for the transponder scenarios demonstrate the intuitive result that greater percentages of equipped trucks yield greater benefits. Each truck that does not have to enter the station not only saves time for itself but reduces the arrival rate within the station, the average queue length, the time spent in line by trucks in the queue, and the frequency of queue overflow. However, the low market penetration anticipated by ISP (5% to 10%) is not sufficient to make significant improvements. It takes 40% to 50% of trucks with transponders to make significant improvements, and such large percentages do not appear likely in the near future.

The WIM scale is very effective in reducing the number of trucks that must be weighed at the static scale. With the given distribution of truck types and truck weights, the majority of trucks are measured as weighing under the 65,000 threshold, even accounting for some error in the WIM scale measurement. The significant reduction in the number of trucks to wait in the queue leads to significant reductions in the average queue length, the time spent in line by trucks in the queue, and the frequency of queue overflow. One drawback to the WIM scale is that the station operator has less of an opportunity to scan the truck and driver to safety concerns.

#### 9.1.2 Results for Lower Traffic Load Scenarios

The significant congestion demonstrated by the base case scenario is primarily a result of the vehicle arrival rate, estimated from data collected at the Edinburgh SHRP site. On the chance that data collected at that site during ten days in April 1998 was too high to represent typical peak hour arrival rates at the Seymour station, Mitretek ran the same ten scenarios with 20% less traffic to simulate a less demanding load. Each measure of effectiveness improved slightly in comparison to the corresponding scenario with base arrival rate. However, significant congestion was still present in the base case scenario, and no congestion-reduction strategy was completely successful except the WIM scale. The relative effectiveness of the various strategies remained the same.

### **9.1.3 Results for Alternate WIM Scenarios**

Mitretek ran the WIM scenario again with the traffic load increased by 20% and by 40%, in accord with an independent forecast of growth in the number of trucks. Mitretek also ran the same three scenarios with the WIM scale threshold set at 75,000 pounds rather than 65,000 pounds. As expected, the results showed increasing congestion as the traffic levels increased, but still well below the level of congestion seen for the base arrival rate with other congestion-reduction strategies. With an arrival rate at the static scales less than the weighing rate, the responsiveness of queue length, average station transit time, and station closing frequency to arrival frequency could be seen. As expected, raising the WIM threshold from 65,000 pounds to 75,000 pounds significantly reduced the queues, waiting times, and closing times even more.

## **9.2 McCook Port of Entry**

This section presents observations and conclusions about the base scenario for the McCook port of entry and for the alternate scenarios in comparison to the base scenario.

### **9.2.1 Results for Base Case Scenarios**

The measures of effectiveness for the base case scenario confirm the presence of congestion at the McCook weigh station during peak periods. During each simulation run of the current peak period scenario with the average truck arrival rate exceeding the average weighing rate at the scales, the queue of trucks waiting in line backed up nearly to the highway on several occasions. During those occasions, the scales were closed and all trucks, including overweight or unsafe trucks, were permitted to proceed without any enforcement. SDDOT staff and weigh station operators confirmed that the results of the base case scenario are consistent with their actual experience.

The problem of queue overflow grows significantly when an increase of 20% or 30% in the average traffic arrival rate is simulated, causing the time the scales are closed to more than double. With the expectation that truck traffic will increase by 20% to 30% on South Dakota highways over the next seven years, it is evident that the current McCook facility will often be overwhelmed.

### **9.2.2 Results for the First Alternate Scenario**

The first alternate scenario represents the operation of a replacement station with a WIM scale, a bypass lane, and an operating policy of sending to the static scales a randomly-selected 10 percent of the trucks over 80,000 pounds gross weight plus all trucks exceeding maximum axle weight limitations (Mitretek assumed 10 percent of the trucks over 80,000 pounds gross weight exceeded axle weight limitations). The results of the simulations showed that the WIM scale and operating policy would be very effective in reducing the number of trucks that must be weighed at the static scale. With the distribution of truck types and truck weights supplied by SDDOT, one to two percent of the simulated trucks were overweight. When only 20 percent of those overweight trucks were sent to the scales, the queue length and the time spent waiting in line were cut nearly to zero. The number of trucks weighed was very small. The frequency of queue overflow was cut to zero. Even with a growth in traffic of 20 or 30 percent the overflow/congestion problem is completely eliminated.

### **9.2.3 Results for the Second Alternate Scenario**

The second alternate scenario modeled the same replacement station configuration as the first alternate case, but the operating policy was changed to direct all trucks measured over a 70,000 pound threshold by the WIM scale to the static scales. This scenario was also sufficient to reduce congestion

to very low levels. The number of trucks in the queue was significantly reduced and the time the scales were closed because of queue overflow was cut to zero, even with a growth in traffic of 20 or 30 percent. The difference in results between this scenario and the previous one (the lower and upper bound for overweight trucks sent to the static scales) was small, suggesting that the precise percentage of axle weight violations or the percentage of gross weight violations sent to the static scales does not make a significant difference.

#### **9.2.4 Conclusions**

The congestion level at the current McCook facility during peak period will persist and will increase as truck traffic levels increase. The safety risk to traffic from queue backups, the workload of the station operator, and the time spent by trucks waiting in line will increase. More overweight and unsafe trucks will be missed because the scales must be closed to prevent overflow.

The construction of a replacement station with a WIM scale and an operating policy permitting most trucks to bypass the static scales would eliminate the congestion problem for current and project traffic loads. Truck queue lengths would not reach levels requiring the scales to close to prevent overflow. The state would be able to target overweight trucks for weighing and enforcement and would be able to spend more time inspecting trucks with safety or driver credential concerns. In addition, all trucks would experience a reduction in delay, since most trucks would not have to stop at all and those trucks that must be weighed would wait in line significantly less time.

One drawback to the WIM scale is that the station operator has a reduced opportunity to scan the truck and driver for safety concerns as trucks pass by farther from the station without stopping.

### **9.3 Lehi Weigh Station**

This section presents observations and conclusions about the base scenario for the Lehi weigh station and for the alternate scenarios in comparison to the base scenario.

#### **9.3.1 Results for Base Case Scenarios**

The measures of effectiveness for the base case scenario with base transponder percent confirm the presence of congestion at the Lehi weigh station during peak periods. During simulation of the current peak period with the average truck arrival rate exceeding the average weighing rate at the scales, the queue of trucks waiting in line backed up nearly to the highway on several occasions. During those occasions, the station and the scales were closed, and all trucks, including overweight or unsafe trucks, were permitted to proceed without any enforcement. Much more frequently, the queue for the static scale overflowed, forcing all trucks in the station to take the bypass lane, and enabling some overweight or unsafe trucks to escape enforcement. AHTD staff confirmed that the results of the base case scenario are consistent with actual experience.

Increased use of transponders allowing trucks to bypass the station reduced the problem of queue overflow. However, since overweight or unsafe trucks could have transponders, the number of problem trucks apprehended does not increase.

#### **9.3.2 Results for the Dual Scales Configuration**

The first alternate configuration represents the addition of a second static scale, doubling the weighing capacity of the station. For all modeled levels of transponder equipage, the second scale sufficed to eliminate station closings and nearly eliminate overflow onto the bypass lane. The doubled weighing

capacity exceeded the arrival rate of over axle weight trucks, so long queues to the static scales did not develop. The average station transit time was less because of shorter queues. However, as for the base case configuration, overweight or unsafe trucks that have transponders may skip the station and escape enforcement.

### **9.3.3 Results for the Mainline WIM Scale Configuration**

The second alternate configuration modeled the addition of a mainline WIM scale in advance of the station. Since the mainline WIM scale permitted only trucks that had a transponder but also did not exceed maximum axle weight to bypass the station, this configuration created more congestion in the station than the base case configuration. Queue lengths and station transit time were the longest for this configuration. On the other hand, more overweight trucks were detected and cited, so the enforcement level of the station was increased over the base case scenarios. The percentage of trucks with transponders did not make a significant difference to the amount of time the static scale queue and the station entrance ramp queue overflowed. These times were the greatest of any of the configurations.

### **9.3.4 Results for the Combination Configuration**

The third alternate configuration modeled the combination of the dual scales and the mainline WIM scales. The addition of the second scale reduced the congestion and resulting queue overflow, and the addition on the mainline WIM scale reduced the number of overweight trucks that were missed. Thus the combination configuration maximizes the number of trucks weighed and the number of problem trucks caught, while minimizing station congestion.

### **9.3.5 Conclusions**

The congestion level at the current Lehi facility during peak period will persist and will increase as truck traffic levels increase. The safety risk to traffic from queue backups, the workload of the station operator, and the time spent by trucks waiting in line will increase. More overweight and unsafe trucks will be missed because the scales must be closed to prevent overflow.

The addition of a mainline WIM scale would increase enforcement effectiveness, but would increase congestion within the station and would increase the number of times the queues would overflow in the station. The addition of a second static scale would significantly reduce queue overflow, but would not significantly increase the number of missed overweight trucks. Adding both options to the station would accomplish both goals, although it would be the most expensive.

Improvement in enforcement could also be made if the management of transponders guaranteed that a truck could not carry a transponder, or the transponder would not authorize station bypass, unless the truck were previously certified as meeting weight and safety regulations. This change would accomplish the same results as the mainline WIM scale.

## TABLE OF ACRONYMS

AHTD	Arkansas Highway and Transportation Department
CVO	Commercial Vehicle Operations
FHWA	Federal Highway Administration
INDOT	Indiana Department of Transportation
ISP	Indiana State Police
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
OMC	Office of Motor Carriers
OOS	Out-of-Service
PRT	Perception-reaction time
PT	Perception time
RT	Reaction time
SDDOT	South Dakota Department of Transportation
SHRP	Strategic Highways Research Program
VIN	Vehicle Identification Number
VMS	Variable Message Sign
WIM	Weigh-in-Motion



## References

1. *Best Practices for Commercial Vehicle Monitoring Facilities Design*, Publication No. FHWA-SA-96-001, September 1995, U.S. Department of Transportation, Federal Highway Administration, Office of Motor Carriers, Washington, DC.
2. Glassco, R.A., 1999, *Westa Version 2.3 User Guide*, Mitretek Systems, Washington, DC.
3. *Advantage I-75 Mainline Automated Clearance Program*, August 1998, Iowa State University.
4. *States' Successful Practices Weigh-in-Motion Handbook*, Publication No. FHWA-SA-96-001, September 1995, U.S. Department of Transportation, Federal Highway Administration, Office of Motor Carriers, Washington, DC.
5. Weng, Ying, *Analysis Procedures for Queue and Delay at Weigh Facilities*, Appendix C to Reference 1.
6. Facts About the Trucking Industry, Team 2000, Washington, DC.



## Appendix A Base Case Input File for Seymour

This appendix presents a complete listing of the input file defining the Seymour base scenario. Variations of this file defining the alternate scenarios are discussed in sections 3.2 through 3.5.

```
Seymour Base Scenario scenario
runLength:      120      # run for two hours (peak period of 3-5 p.m.)
randomSeed_truck: 241
randomSeed_link: 47
avgCreatTime:   2.56      # peak hour 4-5 p.m.
maxWt:          80000     # <- maxWt for static scales
Timestep .1

[TruckInfo]
Class 2 Cars & motorcycles
maxAccRange:    2.8      6.3      .009      #
maxDecRange:    17.3     20.7     .30       # (mi/hr/s)
weightRange:    0        6000     # (lbs)
weightDistrib:  0.0 0.0 4.1 9.9 31.4 27.3 14.9 6.6 4.1 1.7 (%)
lengthRange:    10 20      # (ft)
lengthDistrib:  0.0 0.0 1.7 7.4 19.0 28.9 27.3 10.7 5.0 0.0 # %

Class 3 2-axle 4-tire (Pickup trucks)
maxDecRange:    16.8     18.6     .30
lengthDistrib:  0.0 0.0 96.2 0.0 0.2 1.5 1.9 0.3 0.0

Class 4 Buses
maxDecRange:    16.8     18.6     .30
lengthRange:    30 40
lengthDistrib:  0.0 0.0 96.2 0.0 0.2 1.5 1.9 0.3 0.0

Class 5 2-axle 6-tire single units
weightRange:    0 100000
weightDistrib:  59.6 32.4 7.4 0.5 0.0 0.0 0.0 0.0 0.0 0.0
lengthRange:    10 50      # (ft)
lengthDistrib:  0.0 2.4 64.1 23.6 9.9 0.0 0.0 0.0 0.0 0.0

Class 6 3-axle single units
maxAccRange:    1.3      2.6      .009      #
maxDecRange:    8.2      10.9     .30       # (mi/hr/s)
weightRange:    0        100000  # (lbs)
weightDistrib:  0.3 40.3 32.9 13.6 9.0 2.6 1.1 0.2 0.0 0.0 0.0 # (lbs)
lengthRange:    0 50
lengthDistrib:  0.0 0.0 0.8 18.7 72.3 8.2 0.0 0.0 0.0 0.0

Class 7 4 or more axles, single unit
weightRange:    0 100000
weightDistrib:  0.0 0.2 1.6 2.9 7.1 9.1 55.5 22.7 0.7 0.2 # (%)
lengthRange:    0 50
lengthDistrib:  0.0 0.0 0.0 11.5 50.0 34.6 3.8 0.0 0.0 0.0

Class 8 4 or fewer axles, single trailer
weightRange:    0 100000
weightDistrib:  0.1 5.7 27.3 36.1 22.9 7.5 0.4 0.0 0.0 0.0
lengthRange:    20 70      # (ft)
```

lengthDistrib: 0.0 6.8 22.4 35.1 16.4 7.4 6.5 4.2 1.1 0.0

Class 9 5-axle, single trailer

weightRange: 0 100000

weightDistrib: 0.0 1.5 6.9 16.3 15.2 16.1 16.0 24.2 3.8 0.0

lengthRange: 35 85

lengthDistrib: 0.2 0.6 2.1 10.0 37.1 46.0 3.9 0.2 0.0 0.0

Class 10 6 or more axles, single trailer

weightRange: 0 100000

weightDistrib: 0.0 0.3 3.1 14.4 14.6 10.3 11.5 18.8 14.6 12.3 # (%)

lengthRange: 20 90

lengthDistrib: 0.0 0.0 0.9 8.8 31.0 27.9 27.4 3.5 0.4 0.0

Class 11 5 or fewer axles, multi-trailer

weightRange: 0 100000

weightDistrib: 0.0 0.0 0.4 5.6 9.2 21.5 38.9 22.9 1.5 0.0 # (%)

lengthRange: 20 90

lengthDistrib: 0.0 0.0 0.9 8.8 31.0 27.9 27.4 3.5 0.4 0.0

Class 12 6 axles, multi-trailer

weightRange: 0 100000

weightDistrib: 0.0 0.0 0.0 5.8 12.4 18.2 31.4 26.1 5.0 1.1 # (%)

lengthDistrib: 0.0 0.0 0.0 0.0 0.0 0.0 26.4 36.8 36.8 0.0

Class 13 7 or more axles, multi-trailer

weightRange: 0 100000

weightDistrib: 0.0 0.0 0.0 2.0 2.0 7.8 3.9 3.9 17.6 62.7 # (%)

lengthDistrib: 0.0 0.0 0.0 0.0 0.0 0.0 26.4 36.8 36.8 0.0

ClassDistribution 2 origins

Link	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13
11	0.0	33.3	29.0	0.6	3.8	0.7	0.3	2.4	28.1	0.1	1.5	0.2	0.0
1	0.0	62.6	26.0	0.2	1.9	0.4	0.0	0.2	8.5	0.0	0.2	0.0	0.0

[Attributes]

#	name	cab color	trailer color	%	expr	%	expr
#	----	-----	-----	---	-----	---	-----
1	"car"	yellow	yellow	100	{ c2 }		
2	"truck"	default	default	100	{ ( not c2 ) and ( not c3 ) and ( not c4 ) }		
3	"overweight"	default	lightred	owt	{ }		
4	"safety check"	default	black	2	{ 2 }		
5	"credential check"	lightred	default	4	{ 2 }		
6	"weighed"	default	default	0	{ }		
7	"fixable"	default	default	100	{ 3 }	100	{ 5 }
8	"2nd try okay"	lightblue	lightblue	0	{ }	90	{ 4 }
9	"OOS"	black	black	0	{ }		
10	"bypassed"	default	white	0	{ }		
11	"bypass overwt"	default	default	0	{ }		
12	"legal in station"	default	default	0	{ }		

[GraphInfo]

Stat "Total number of trucks" Count 2

Stat "Overweight trucks" Count 3

Stat "Trucks weighed" Count 6

Stat "Trucks bypassed" Count 10

```

Stat  "Overweights bypassed"  Count 11
Stat  "Average time"          Time 2
Stat  "Queue length"          QueueLen
View 1  -44 1265 -159 823
View 2   872 2181 -159 823
View 3  1658 2967 -159 823
View 4  3857 4695 -108 521
View 5  4544 5214  -45 458

```

```

[Tests]
#  name                      ret expression  assignments
#  ----                      -
2  "trucks right"           A { 2 } { }
3  "tag weighed"            A { 2 } { 6 }
4  "to parking lot"         A { ( 3 or 4 or 5 ) and ( not 8 ) } { }
5  "safety check"           A { not 7 } { 9 }
6  "fix some"               A { 7 } { 8 }
7  "tag misses"             A { 2 } { 10 }
8  "tag ovwt misses"        A { 3 } { 11 }
9  "legal in station"       A { ( not 3 ) and ( not 4 ) and ( not 5 ) } { 12 }

```

```

[ServiceTimes]
#  name                      expression  random type parms
#  ----                      -
1  "weighing time"          { 8 } Constant 0 { } Erlang 7
2  "inspection time"        { 5 } Erlang 60 { 3 } Erlang 120 { } Erlang 1200

```

```

[LinkInfo]
#  type  ahead spd  start x&y  end x&y  key terms
#  ----  -- -- --  ----
1  Orig   2 - 55      0 365 200 365 A .37
2  Trans  3 - 55      200 365 1700 365 RL 12
3  Branch 4 5 55     1700 365 2000 365 T 2
4  Trans  6 - 55     2000 365 2450 365
5  Trans 14 - 55     2000 365 2100 350 Y
6  Trans  7 - 55     2450 365 3000 365
7  Trans  8 - 55     3000 365 4000 365 RL 16
8  Trans  9 - 55     4000 365 5300 365
9  Dest   - - 55     5300 365 5500 365
11 Orig  12 - 55      0 350 200 350 A .63
12 Trans 14 - 55      200 350 2100 350 LL 2
14 Trans 15 - 55      2100 350 2450 350
15 Branch 16 21 55     2450 350 3000 350 T 2 LL 6
16 Branch 17 17 55     3000 350 4000 350 T 7 LL 7
17 Branch 18 18 55     4000 350 5300 350 T 8 LL 8
18 Dest   - - 55     5300 350 5500 350
21 Trans 22 - 35     3000 350 3900 270 C .50 O .0 SC Q
22 Trans 23 - 25     3900 270 4130 250 Q AS 33
23 Branch 24 24 20     4130 250 4275 250 Q T 9
24 Branch 25 31 5      4275 250 4410 250 ST 1 T 4 Q
25 Branch 26 26 25     4410 250 4580 250 T 3
26 Trans 27 - 25     4580 250 4680 270
27 Trans 28 - 35     4680 270 4930 320
28 Trans 18 - 55     4930 320 5300 350 Y
31 Trans 32 - 10     4410 250 4450 160 CC 4403 192
32 Park  33 33 5      4450 160 4150 100 ST 2 T 5 OC 4388 94 PS 16
33 Branch 23 23 10     4150 100 4130 250 T 6 CC 4157 176

```

38 Bldg       -   -   -   4250   210 4302   236   "Office"

[End]

## Appendix B Base Case Input File for McCook

This appendix presents a complete listing of the input file defining the McCook base scenario. Variations of this file defining the alternate scenarios are discussed in sections 4.3 through 4.5.

```
McCook 100% Base case scenario
runLength:      120      # run for two hours
randomSeed_truck: 101
randomSeed_link: 11
avgCreatTime:   10                               #
maxWt:          80000                               # <- maxWt for static scales
TimeStep .1

[TruckInfo]
Class 2  Cars
maxAccRange:    2.8    6.3      .009      # (mi/hr/sec)
maxDecRange:    17.3   20.7     .30       # (mi/hr/s)
weightRange:    0      6000      # (lbs)
weightDistrib:  0.0 0.0 4.1 9.9 31.4 27.3 14.9 6.6 4.1 1.7 (%)
lengthRange:    10 20                               # (ft)
lengthDistrib:  0.0 0.0 1.7 7.4 19.0 28.9 27.3 10.7 5.0 0.0 # %

Class 3  2-axle 4-tire (Pickup trucks)
maxDecRange:    16.8   18.6     .30
lengthDistrib:  0.0 0.0 96.2 0.0 0.2 1.5 1.9 0.3 0.0

Class 4  Buses
maxDecRange:    16.8   18.6     .30
lengthRange:    30 40
lengthDistrib:  0.0 0.0 96.2 0.0 0.2 1.5 1.9 0.3 0.0

Class 5  2-axle 6-tire single units
weightRange:    0      100000      # (lbs)
weightDistrib:  0.7 23.1 28.6 20.4 14.3 12.2 0.0 0.0 0.7 0.0 # (%)
lengthRange:    0      50          # (ft)
lengthDistrib:  0.0 0.0 2.4 64.1 23.6 9.9 0.0 0.0 0.0 0.0

Class 6  3-axle single units
maxAccRange:    1.3    2.6      .009      # (mi/hr/sec)
maxDecRange:    12.8   16.0     .30       # (mi/hr/sec)
weightDistrib:  0.0 0.0 0.0 84.6 15.4 0.0 0.0 0.0 0.0 0.0 # (%)
lengthDistrib:  0.0 0.0 0.8 18.7 72.3 8.2 0.0 0.0 0.0 0.0

Class 7  4 or more axles, single unit
weightDistrib:  0.0 0.0 9.6 38.6 43.4 8.4 0.0 0.0 0.0 0.0 # (%)
lengthDistrib:  0.0 0.0 0.0 11.5 50.0 34.6 3.8 0.0 0.0 0.0

Class 8  4 or fewer axles, single trailer
weightDistrib:  0.0 20.6 14.7 8.8 2.9 2.9 17.6 32.4 0.0 0.0 # (%)
lengthRange:    20 70                               # (ft)
lengthDistrib:  0.0 6.8 22.4 35.1 16.4 7.4 6.5 4.2 1.1 0.0

Class 9  5-axle, single trailer
weightDistrib:  0.0 0.0 0.1 3.9 13.3 15.7 15.7 48.5 2.7 0.1 # (%)
lengthRange:    35 85
```

lengthDistrib: 0.2 0.6 2.1 10.0 37.1 46.0 3.9 0.2 0.0 0.0

Class 10 or more axles, single trailer

weightRange: 10000 110000

weightDistrib: 0.0 0.0 0.0 1.9 11.3 17.0 24.5 24.5 13.2 7.6 # (%)

lengthDistrib: 0.0 0.0 0.9 8.8 31.0 27.9 27.4 3.5 0.4 0.0

Class 11 5 or fewer axles, multi-trailer

weightRange: 20000 120000

weightDistrib: 0.0 1.9 10.1 33.5 42.4 8.2 1.9 1.3 0.0 0.6 # (%)

lengthDistrib: 0.0 0.0 0.0 0.0 0.0 33.4 33.3 11.1 22.2 0.0

Class 12 6 axles, multi-trailer

weightRange: 20000 120000

weightDistrib: 0.0 1.9 10.1 33.5 42.4 8.2 1.9 1.3 0.0 0.6 # (%)

lengthDistrib: 0.0 0.0 0.0 0.0 0.0 0.0 26.4 36.8 36.8 0.0

Class 13 7 or more axles, multi-trailer

weightRange: 70000 170000

weightDistrib: 0.0 0.0 0.0 0.0 11.1 22.2 11.1 11.1 22.2 22.3 # (%)

lengthRange: 55 105

lengthDistrib: 10.7 9.0 6.3 1.7 4.2 3.6 10.7 25.2 27.0 1.7

ClassDistribution 2 origins

Link	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13
0	0.0	44.6	27.4	0.3	3.5	1.0	0.0	17.0	3.1	0.1	2.3	0.4	0.3
1	0.0	74.0	21.2	0.0	0.8	1.6	0.0	0.8	1.6	0.0	0.0	0.0	0.0

[GraphInfo]

Stat "Total number of trucks" Count 2

Stat "Overweight trucks" Count 3

Stat "Waved through" Count 15

Stat "Violators missed" Count 16

Stat "Average time" Time 12

Stat "Trucks in queue" QueueLen

View 1 1817 2857 -237 545

View 2 1160 2701 -237 545

View 3 784 1317 57 457

View 4 48 881 -96 529

View 5 888 1107 135 298

View 6 4160 4501 -36 221

GraphicsMode d

[Attributes]

#	name	cab color	trailer color	%	expr	%	expr
#	----	-----	-----	---	-----	---	-----
1	"car"	yellow	yellow	100	{ c2 }		
2	"truck"	default	default	100	{ ( not c3 ) and ( not c2 ) and ( not c4 ) }		
3	"overweight"	default	lightred	owt	{ }		
4	"safety check"	default	black	2	{ 2 }		
5	"credential check"	lightred	default	4	{ 2 }		
6	"fixable"	default	default	100	{ 3 }	100	{ 5 }
7	"inspected"	lightblue	lightblue	0	{ }		
8	"OOS"	black	black	0	{ }		
10	"held at scales"	default	default	50	{ 3 }		

12 "legal"	default	default	100 { 2 and ( not 3 ) and ( not 4 )
and ( not 5 ) }			
15 "waved through"	default	lightgray	0 { }
16 "bad misses"	default	brown	0 { }

#### [Tests]

#	----	---	-----	-----
1	"trucks right"	A	{ 2 }	{ }
2	"to parking lot"	A	{ 3 or 4 or 5 }	{ }
3	"safety check"	A	{ not 6 }	{ 8 }
4	"fix some"	A	{ 6 }	{ 7 }
6	"missed truck"	A	{ 2 }	{ 15 }
7	"bad miss"	A	{ 15 and ( 3 or 4 or 5 ) and ( not 7 ) }	{ 16 }

#### [ServiceTimes]

#	name	expression	random type parms
#	----	-----	-----
1	"weighing time"	{ 10 } Erlang 90	{ } Erlang 41
2	"inspection time"	{ 5 } Erlang 900	{ 4 } Erlang 3000 { 3 } Erlang 1200

#### [LinkInfo]

#	type	ahead	spd	dimensions	typespecific
#	----	--	--	-----	-----
0	Orig	2	- 55	4400 100 3900 100	A .8 LL 1
1	Orig	3	- 55	4400 80 3900 80	A .2 RL 0
2	Trans	6	- 55	3900 100 2700 100	LL 3
3	Trans	4	- 55	3900 80 3200 80	RL 2
4	Branch	23 5	55	3200 80 2800 80	T 1
5	Trans	6	- 55	2800 80 2700 100	Y
6	Branch	7 9	55	2700 100 2200 100	T 1 LL 24
7	Trans	8	- 55	2200 100 100 100	LL 25
8	Dest	-	- 55	100 100 0 100	
9	Trans	10	- 35	2200 100 1300 217	Q
10	Trans	11	- 15	1300 217 1200 230	Q AS 22
11	Branch	16 12	10	1200 230 920 230	T 1 Q
12	Branch	17 20	5	920 230 860 230	ST 1 T 2 CL 9 C .5 O .2 SC
13	Trans	14	- 10	1200 230 1170 220	
14	Trans	15	- 10	1170 220 880 220	
15	Trans	17	- 25	880 220 860 230	Y
16	Branch	17 17	10	920 231 860 231	T 6
17	Branch	18 18	35	860 230 730 230	T 7
18	Trans	8	- 55	730 230 100 100	Y
20	Trans	21	- 10	860 230 870 370	CC 882 297
21	Park	22 22	5	870 370 1160 350	ST 2 T 3 OC 970 440 PS 10
22	Branch	13 13	10	1160 350 1200 230	T 4 CC 1170 287
23	Trans	24	- 55	2800 80 2700 80	
24	Trans	25	- 55	2700 80 2200 80	
25	Dest	-	- 55	2200 80 0 80	
40	Bldg	-	- 0	910 250 1000 280	"Office"
41	Bldg	-	- 0	920 224 932 234	"Scale"

[End]

## Appendix C Base Case Input File for Lehi

This appendix presents a complete listing of the input file defining the Lehi base scenario. Variations of this file defining the alternate scenarios are discussed in sections 5.3 through 5.5.

```
Lehi Base Case Scenario
runLength:      120      # min. (run for two hours)
randomSeed_truck: 20
randomSeed_link: 47
avgCreatTime:   3.76    # constant fast arrivals
maxWt:          80000    # <- maxWt for static scales
Timestep .2

[TruckInfo]
Class 2  Cars
maxAccRange:    2.8      6.3      .009      # (mi/hr/sec)
maxDecRange:    17.3     20.7     .30       # (mi/hr/sec)
weightRange:    0        6000     # (lbs)
weightDistrib:  0.0 0.0 4.1 9.9 31.4 27.3 14.9 6.6 4.1 1.7 # (%)
lengthRange:    10 20      # (ft)
lengthDistrib:  0.0 0.0 1.7 7.4 19.0 28.9 27.3 10.7 5.0 0.0 # %

Class 3  2-axle 4-tire (Pickup trucks)
maxDecRange:    16.8     18.6     .30       # (mi/hr/sec)
lengthDistrib:  0.0 0.0 96.2 0.0 0.2 1.5 1.9 0.3 0.0

Class 4  buses
maxDecRange:    16.8     18.6     .30
lengthRange:    30 40
lengthDistrib:  0.0 0.0 96.2 0.0 0.2 1.5 1.9 0.3 0.0

Class 5  2-axle 6-tire single units
weightRange:    0        100000    # (lbs)
weightDistrib:  0.7 71.0 18.5 6.9 1.9 0.7 0.3 0.0 0.0 0.0
lengthRange:    10      50        # (ft)
lengthDistrib:  0.0 2.4 64.1 23.6 9.9 0.0 0.0 0.0 0.0 0.0

Class 6  3-axle single units
maxAccRange:    1.3      2.6      .009      #
maxDecRange:    8.2      10.9     .30       # (mi/hr/s)
weightDistrib:  0.6 35.8 34.0 11.9 6.0 7.5 2.7 0.7 0.6 0.2 # (%)
lengthRange:    0        50
lengthDistrib:  0.0 0.0 0.8 18.7 72.3 8.2 0.0 0.0 0.0 0.0

Class 7  4 or more axles, single unit
weightrange: 20000 120000
weightDistrib:  2.3 4.5 9.1 54.5 20.4 0.0 2.3 2.3 0.0 4.6 # (%)
lengthDistrib:  0.0 0.0 0.0 11.5 50.0 34.6 3.8 0.0 0.0 0.0

Class 8  4 or fewer axles, single trailer
weightDistrib:  2.3 4.5 9.1 54.5 20.4 0.0 2.3 2.3 0.0 4.6 # (%)
lengthRange:    20 70      # (ft)
lengthDistrib:  0.0 6.8 22.4 35.1 16.4 7.4 6.5 4.2 1.1 0.0
```



Class 9 5-axle, single trailer  
weightRange: 20000 120000  
weightDistrib: 14.1 16.2 14.6 13.5 17.7 12.4 5.2 2.4 1.4 2.5 # (%)  
lengthRange: 35 85  
lengthDistrib: 0.2 0.6 2.1 10.0 37.1 46.0 3.9 0.2 0.0 0.0

Class 10 6 or more axles, single trailer  
weightrange: 20000 120000  
weightDistrib: 5.1 7.3 11.2 17.0 19.4 17.6 12.0 6.2 2.7 1.5 # (%)  
lengthRange: 20 90  
lengthDistrib: 0.0 0.0 0.9 8.8 31.0 27.9 27.4 3.5 0.4 0.0

Class 11 5 or fewer axles, multi-trailer  
weightRange: 20000 120000  
weightDistrib: 10.9 12.0 19.3 22.9 18.6 7.0 4.3 2.5 1.8 0.7 # (%)  
lengthRange: 20 90  
lengthDistrib: 0.0 0.0 0.9 8.8 31.0 27.9 27.4 3.5 0.4 0.0

Class 12 6 axles, multi-trailer  
weightrange: 20000 120000  
weightDistrib: 7.3 11.8 16.8 20.1 15.5 14.9 7.8 3.7 1.4 0.7 # (%)  
lengthDistrib: 0.0 0.0 0.0 0.0 0.0 0.0 26.4 36.8 36.8 0.0

Class 13 7 or more axles, multi-trailer  
weightrange: 30000 130000  
weightDistrib: 13.4 5.3 16.0 21.3 21.3 12.0 1.3 2.7 2.7 4.0 # (%)  
lengthDistrib: 0.0 0.0 0.0 0.0 0.0 0.0 26.4 36.8 36.8 0.0

ClassDistribution 2 origins

Link	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13
3	0.0	25.7	10.5	1.0	3.1	0.8	0.0	0.5	52.3	0.3	3.0	2.7	0.1
1	0.0	56.6	28.6	1.1	3.3	0.1	0.1	0.1	8.3	0.1	0.1	1.5	0.1

[Attributes]

#	name	cab color	trailer color	%	expr	%	expr
#	----	-----	-----	---	-----	---	-----
1	"car"	yellow	yellow	100	{ c2 }		
2	"truck"	default	default	100	{ ( not c2 ) and ( not c3 ) and ( not c4 ) }		
3	"overweight"	default	lightred	owt	{ }		
4	"over axle weight"	default	default	94	{ 3 }	22	{ 2 and ( not 3 ) }
5	"weighed"	default	default	0	{ }		
6	"safety check"	default	black	2	{ 2 }		
7	"credential check"	lightred	default	4	{ 2 }		
9	"fixable"	default	default	100	{ 3 }	100	{ 7 }
10	"OOS"	black	black	0	{ }		
11	"bypass lane"	default	default	0	{ }		
12	"spilled in station"	default	default	0	{ }		
13	"skipped station"	default	default	0	{ }		
14	"parking lot"	default	default	0	{ }		
15	"missed overwt"	black	default	0	{ }		
16	"missed cred/safe"	white	default	0	{ }		
17	"random"	default	default	50	{ 2 }		
18	"transponder"	lightgreen	default	12	{ 2 }		

[Tests]

#	Name	ret expression	assignments
---	------	----------------	-------------

```

# -----
1 "trucks to rightlane" A { 2 } { }
2 "transponder check" A { 2 and ( not 18 ) } { }
3 "to scales" A { 4 } { }
4 "to parking lot" A { ( 3 or 6 or 7 ) } { }
5 "safety check" A { not 9 } { 10 }
6 "tag bypasses" A { 2 } { 11 }
7 "tag spills" A { 2 } { 12 }
8 "tag skipped station" A { 2 } { 13 }
9 "tag trucks in lot" A { 2 } { 14 }
10 "tag overwt misses" A { 3 and ( not 14 ) } { 15 }
11 "tag miss safe/cred" A { ( 6 or 7 ) and ( not 14 ) } { 16 }
12 "catch some bypass" A { 17 and ( 3 or 6 or 7 ) } { }
13 "bypassers left" A { 17 } { }
14 "tag weighed" A { 2 } { 5 }

```

#### [ServiceTimes]

```

# name expression random type parms
# -----
1 "weighing time" { } Erlang 47
2 "inspection time" { 3 } Erlang 600 { 6 } Erlang 1500 { 7 } Erlang 300
3 "stop on bypass lane" { } Constant 15

```

#### [LinkInfo]

```

# type ahead spd dimensions typespecific
# -----
1 Orig 2 - 55 3370 315 3580 315 RL 3 A .35
2 Trans 6 - 55 3580 315 3995 315 RL 4
3 Orig 4 - 55 3370 300 3580 300 LL 1 A .65
4 Trans 7 - 55 3580 300 3995 300 LL 2
6 Branch 8 9 55 3995 315 4370 315 RL 7 T 1
7 Trans 10 - 55 3995 300 4415 300 LL 6
8 Trans 17 - 55 4370 315 4830 315
9 Trans 10 - 55 4370 315 4415 300 Y
10 Branch 11 21 55 4415 300 4830 300 T 2 LL 8
11 Branch 12 12 55 4830 300 5900 300 LL 17 T 8
12 Branch 13 18 55 5900 300 6500 300 T 13
13 Trans 14 - 55 6500 300 7565 300
14 Branch 15 15 55 7565 300 7665 300 T 10
15 Branch 16 16 55 7665 300 7770 300 T 11
16 Dest - - 55 7770 300 7850 300
17 Trans 19 - 55 4830 315 6545 315
18 Branch 19 19 55 6500 300 6545 315 Y T 11
19 Branch 20 20 55 6545 315 7565 315 T 10
20 Dest - - 55 7565 315 7850 315
21 Branch 22 31 20 4830 300 6190 240 T 3 Q SC C .6 O .2
22 Branch 23 23 15 6190 240 6700 240 T 6
23 Branch 24 25 15 6700 240 6800 240 T 12
24 Trans 27 - 15 6800 240 6845 240
25 Branch 27 26 15 6800 240 6845 240 T 12 ST 3 CL 21 C .6 O .2
26 Trans 36 - 15 6845 240 6885 215
27 Trans 28 28 15 6845 240 7180 240
28 Trans 29 - 30 7180 240 7335 280
29 Trans 38 - 40 7335 280 7480 290
30 Trans 36 - 10 6865 225 6885 215
31 Trans 32 - 10 6190 240 6295 225 CL 32 C .65 O .6 Q
32 Branch 39 33 10 6295 225 6845 225 Q T 14

```

33 Branch	34 30	10	6845	225 6865	225	ST 1 T 4 CL 21 C .6 O .2
34 Trans	35 -	15	6865	225 7150	225	
35 Trans	42 -	30	7150	225 7215	245	
42 Trans	29 -	30	7215	245 7335	280	Y
36 Park	37 37	5	6885	215 7210	150	OC 6970 150 ST 2 T 5 PS 14 NQ
37 Branch	38 38	30	7210	150 7480	290	Y T 9
38 Trans	14 -	50	7480	290 7565	300	Y
39 Branch	34 34	10	6845	225 6865	225	T 7
40 Bldg	- -	0	6795	180 6830	210	"Office"
41 Bldg	- -	0	6780	220 6850	230	"Scale"

[GraphInfo]

Stat	"Total number of trucks"	Count	2
Stat	"Number trucks bypassed"	Count	11
Stat	"Skipped station"	Count	13
Stat	"Spilled past scales"	Count	12
Stat	"Overweight trucks"	Count	3
Stat	"Overweights missed"	Count	15

View 1	4311	4976	-17	482
View 2	4960	6000	-157	622
View 3	5688	6988	-255	720
View 4	6721	7387	-17	482
View 5	6988	7653	-17	482
View 6	6707	7047	105	360

GraphicsMode a

[End]